3.0 Dioxins, Furans and Dioxin-like (Coplanar) PCBs

This chapter discussed dioxin, furan and dioxin-like (coplanar) PCB sources, cycling, ecological and human health risks, the number of river miles under fish advisory for various contaminants and the total lake and river acres under advisory, the emerging issue of PBDEs, Toxic Equivalent Factors and Toxic Equivalences, and human health and ecological risk screening criteria. Observed levels of dioxins and furans and coplanar PCBs were compared by Reach with ecological and human health screening criteria and, for coplanar PCBs, statistically between Reaches.

Dioxin toxicity, in the twelve fillet composites analyzed, posed a varying risk to both subsistence and recreational fishers and fish-eating wildlife, even when dioxin-like PCB TEQs (a standardized measure of dioxin toxicity) were not included in the risk calculations. Since risk associated with dioxin is not available for the remainder of the fish samples, these PCB TEQs underestimate human health and ecological risk from consumption of Connecticut River fish.

Risk from dioxin-like (coplanar) PCBs was generally lower in upstream Reaches than in downstream Reaches; although this varied by fish species and was different for the humans/mammals, birds or fish that eat them. Dioxin-like PCBs pose a risk to recreational and subsistence fishers and to fish-eating mammals and fish-eating birds.

3.1 Dioxins and Furans

USEPA (1999) notes that, “[D]ioxins are a group of synthetic organic chemicals that contain 210 structurally related individual chlorinated dibenzo-p-dioxins (CDDs) and chlorinated dibenzofurans (CDFs).”

In this document the term ‘dioxin is used to refer to the aggregate of all of these CDDs and CDFs. Dioxins were never produced intentionally, except in very small quantities for research. Rather, as USEPA (1999) notes “they are unintentionally produced as byproducts of incineration and combustion processes, chlorine bleaching in pulp and paper mills, and as contaminants in certain chlorinated organic chemicals.” Dioxins are also produced by some natural processes. Dioxins are widely distributed in the environment because of their persistence and bioaccumulation. Dioxins and PCBs are highly hydrophobic. They are highly resistent to chemical and biological degradation, with half-lives of months to years (USEPA 1999; 2001). Dioxins have been detected in all regions of the earth in soil, surface water, sediment, plants and animal tissue (USEPA 1999).

In this document the term ‘dioxin’ is used to refer to the aggregate of all of these CDDs As illustrated in Figure 37, the cycling of dioxin through the environment is a complex process, involving multiple sources, flows, reservoirs, and sinks (USEPA 1994):

“**Sources** to air are dominated by the combustion of wastes and fuels. Sources to water include storm runoff, air deposition, and waste water discharges from certain industrial processess. Contributions to land include air deposition and the land spreading of waste water treatment sludge.

Flows include: air born transport of dioxin vapor and dioxin contaminated particulates; water transport of dioxin contaminated suspended particulates; transport from land through wind and water erosion, transport by biota through trophic exchange, and the movement through commerce contaminated materials.

Reservoirs include soil, sediment and manufactured materials which contain dioxins that are temporarily stored but may later be released into the circulating environment.

Sinks represent the long term storage and isolation of dioxin in undisturbed soil and sediment.”

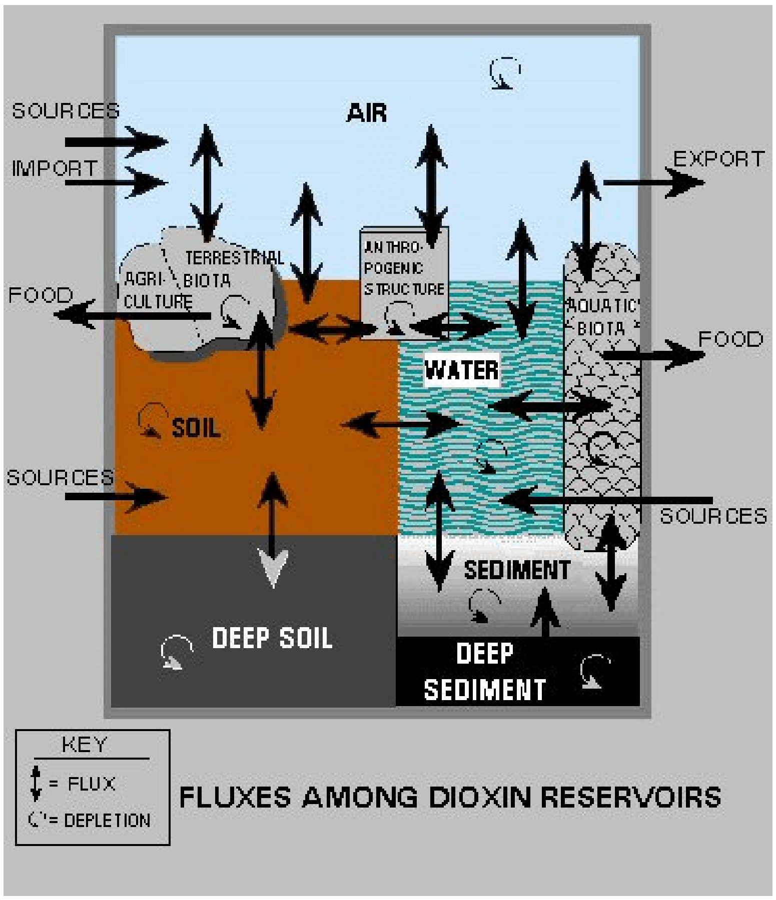

Figure 37. Fluxes among Dioxin Reservoirs (Source: USEPA 1994)

In experimental animals dioxin exposure has lead to death, “toxic effects on the liver, gastroinestinal system, blood, skin, endocrine system, immune system, nervous system, and reproductive system,....developmental effects and liver cancer” (USEPA 1999). Fish may uptake dioxins and PCBs through exposure to contaminated sediment and other routes of exposure (Spacie and others 1995).

USEPA’s (2003) dioxin reassessment found that, “based on all available information, dioxins are potent animal toxicants with potential to produce a broad spectrum of adverse effects in humans.” Dioxins may alter cell growth and development, adversely affecting reproduction and

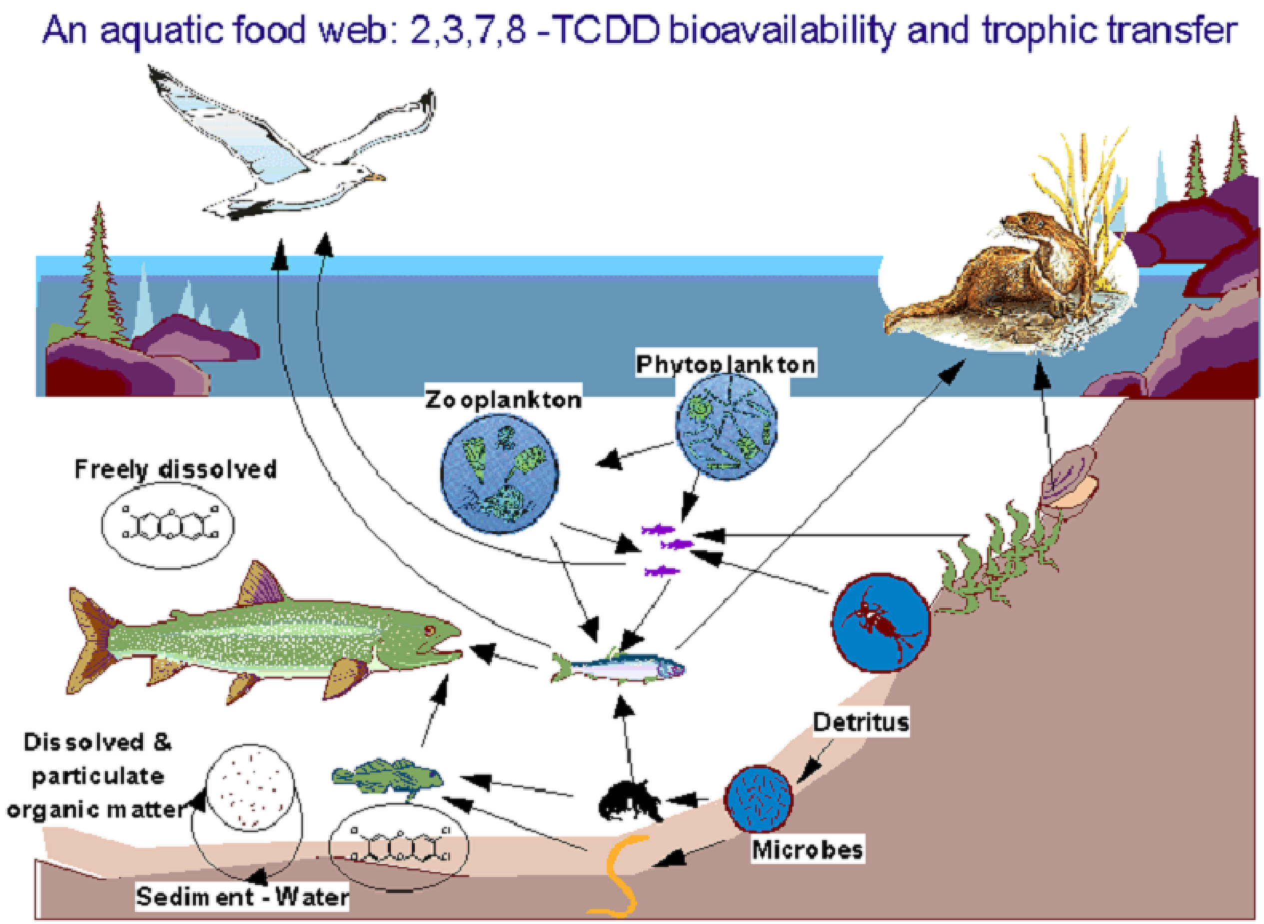

Figure 38. Schematic Model of Dioxin Bioavailability and Trophic Transfer (Source: Dr. Phil Cook, USEPA-ORD, Duluth)

development; suppress immune function and lead to chloracne (a severe acne-like condition that sometimes persists for many years); and may cause cancer. EPA has classified dixoins as 'probable human carcinogens (Group B2)' (USEPA 1999).

Dr. Phil Cook, of EPA's Duluth Research lab, an internationally prominent dioxin researcher, has provided a schematic aquatic food web for dioxin bioavailability and trophic transfer in Figure 38.

In 2003 only 90 fish consumption advisories were issued for dioxin in the conterminous United States, compared to 2,362 advisories for mercury (USEPA 2004b). In 2004 the number of mercury advisories increased to 2,436, with 161 in New England's coastal and freshwaters. In New England there were only 11 active dioxin advisories as of the 2003 data (USEPA 2005). The total number of national dioxin advisories increased in 2004 to 106, with 24 in New England, including coastal and freshwaters. PCBs had

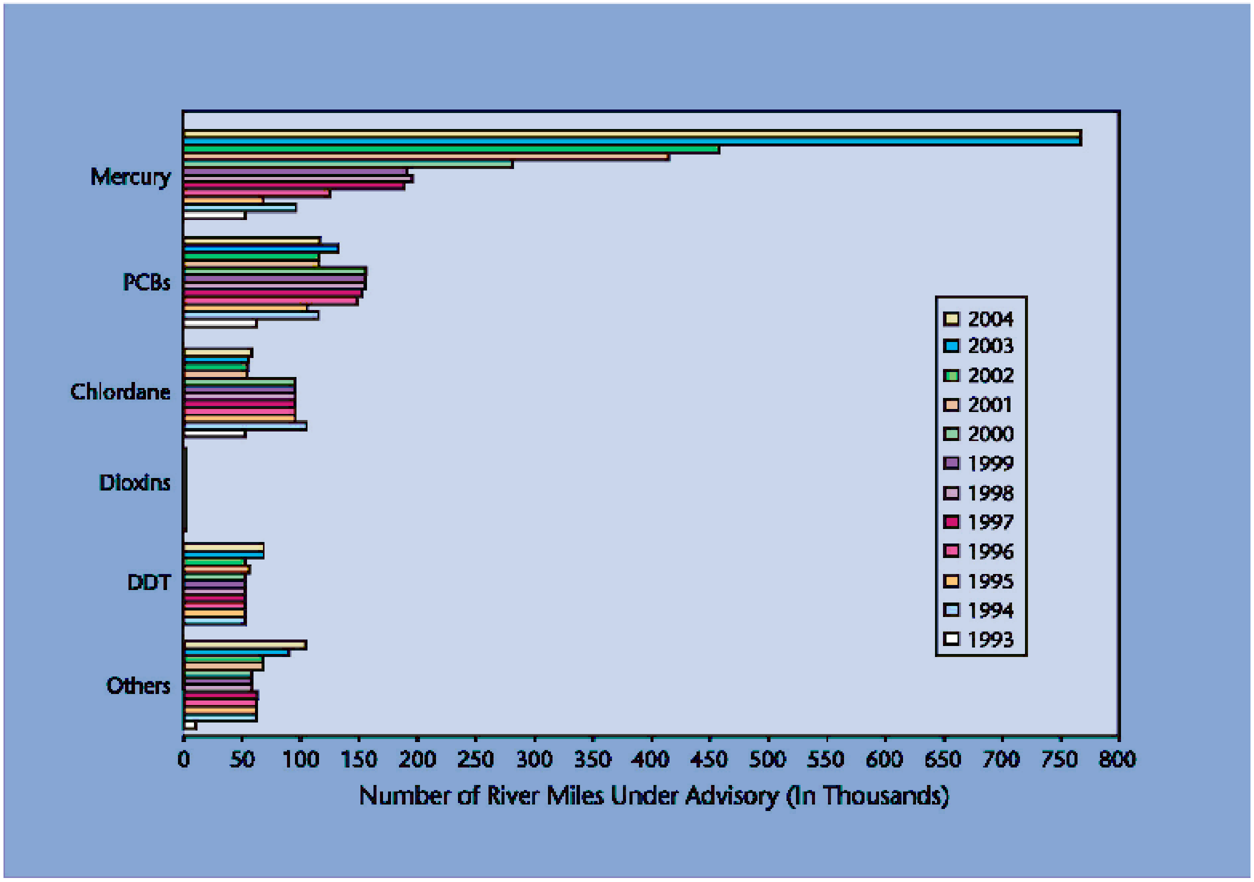

Figure 39. Number of River Miles under Fish Advisory for Various Contaminants (USEPA 2006; http://epa.gov/waterscience/fish/advisories/2004slides.ppt)

873 advisories active in 2004, down from 884 advisories in 2003. Whereas DDT and metabolites had 67 advisories active in 2004, up from 52 in 2003. Chlordane had 79 advisories active in 2004, down from 89 advisories in 2003. One hundred percent of New England's lake acreage and river miles are under advisory as of 2004 because of statewide mercury advisories for sensitive populations.

Figure 39 graphs the changing river miles under fish advisory for DDT, dioxin, PCBs, chlordane, mercury and other contaminants from 1993-2004. This increase likely substantially reflects increased monitoring by the States and Tribes, rather than increased contamination of waters or biota. Figure 40 graphs the percentage of total river miles and lake acres in the conterminous U.S. under fish advisory from 1993-2004.

The current state of knowledge for dioxin in fish tissue, is analogous to that which existed for mercury until the early 1990's, when more widespread sampling began to uncover the geographic extent of the threat. Over 95% of human exposure to dioxin is through ingestion of animal fats. Dioxins have been identified in fish tissue samples,

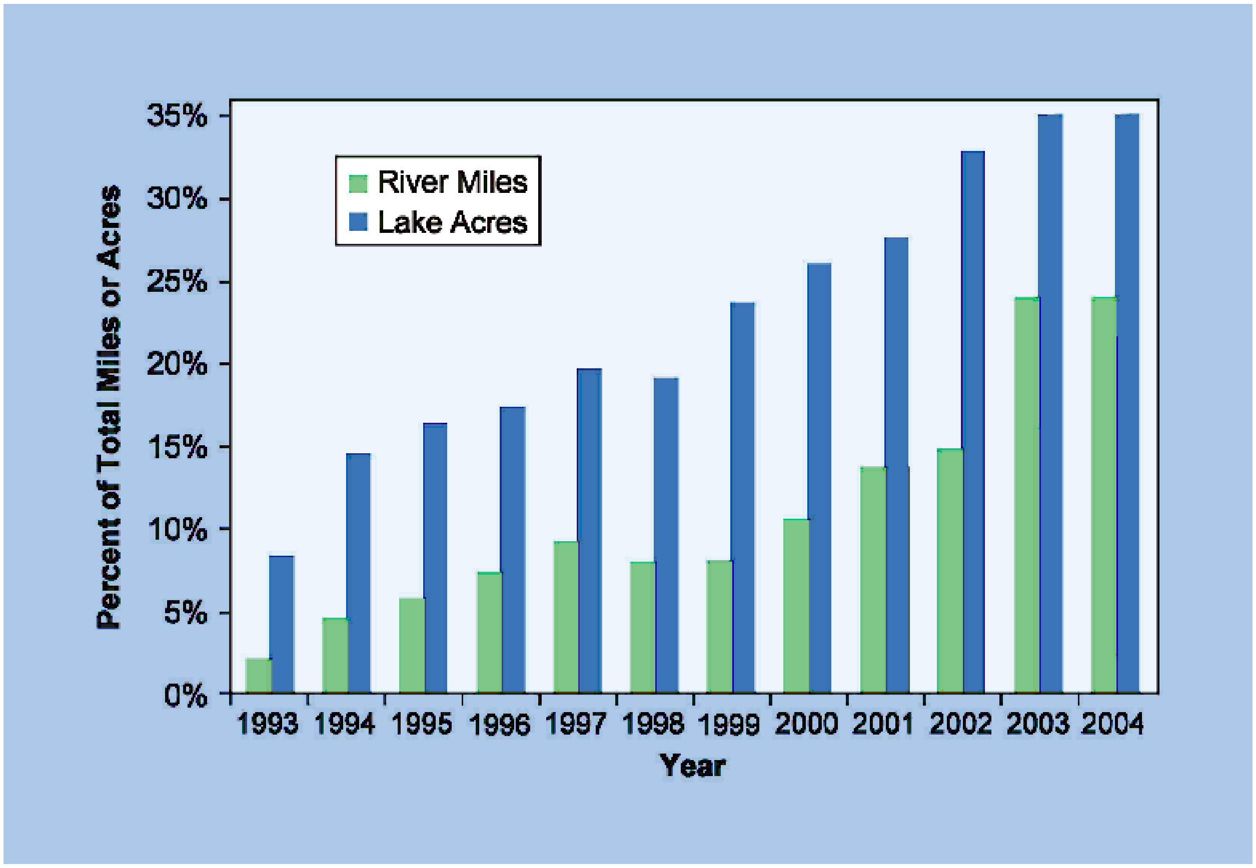

Figure 40. Percent of Total River Miles and Lake Acres under Fish Advisory from 1993-2004 (USEPA 2006; http://epa.gov/waterscience/fish/advisories/2004slides.ppt)

leading to consumption advisories in North America and Europe, for both farmed and wild fish (SCAN 2000; USEPA 2004b). The magnitude of human health and environmental threat from these highly toxic chlorinated contaminants in fish tissue is currently grossly underestimated through under sampling (Stodola and Hellyer 2005). EPA (2002a) notes that poor Americans eat substantially more fish than the average consumer. This under sampling of dioxin in fish constitutes an environmental justice issue as it exposes, particularly vulnerable populations, such as subsistence fishers (e.g. some Asian-American and North American Indian populations) and poor Americans, to unknown levels of health risk (Stodola and Hellyer 2005; Fields 2005). In the current study, owing to the cost of dioxin analysis, only 12 fillet composites were analysed.

It has long been known that dioxins and coplanar PCBs[36] vary widely in their relative toxicity. In 1998 an international workgroup reached a consensus, adopted by the World Health Organization (WHO) and USEPA, on the relative toxicity of dioxins, furans

[36]Co-planar (dioxin-like) PCB toxicity is believed to result primarily from activation of the aryl hydrocarbon receptor, as does toxicity from dioxins and furans. However, likely other toxicity mechanisms also occur.

and coplanar (dioxin-like) PCBs to human, mammalian, fish and bird receptors (Van den Berg and others 1998). EPA had previously used Toxic Equivalence Factors (TEFs) summarized in Barnes and Bellin (1989). The WHO consensus TEF values were based on the state-of-the-science at that time, and will likely be refined as additional knowledge becomes available. All dioxins and coplanar PCBs are normalized relative to 2,3,7,8-TCDD, the most toxic form, which was given a value of 1 (Table 22).

Table 22. World Health Organization Toxic Equivalence Factors (TEFs)[37] for Dioxins, Furans and Dioxin-like (Coplanar) PCBs for Humans, Mammals, Fish and Birds (Van den Berg and others, 1998)

Congener	Humans/Mammals	Fish	Birds
Dioxin Congeners			
2,3,7,8-TCDD	1	1	1
1,2,3,7,8-PentaCDD	1	1	1
1,2,3,4,7,8-HexaCDD	0.1	0.5	0.05
1,2,3,6,7,8-HexaCDD	0.1	0.01	0.01
1,2,3,7,8,9-HexaCDD	0.1	0.01	0.1
1,2,3,4,6,7,8-HeptaCDD	0.01	0.001	<0.001
OctaCDD	0.0001	<0.0001	0.0001
Furan Congeners			
2,3,7,8-TetraCDF	0.1	0.05	1
1,2,3,7,8-PentaCDF	0.05	0.05	0.1
2,3,4,7,8-PentaCDF	0.5	0.5	1
1,2,3,4,7,8-HexaCDF	0.1	0.1	0.1
1,2,3,6,7,8-HexaCDF	0.1	0.1	0.1
1,2,3,7,8,9-HexaCDF	0.1	0.1	0.1
2,3,4,6,7,8-HexaCDF	0.1	0.1	0.1

[37]TEFs have no concentration units (e.g.,ppb or ppm) associated with them. They are dimensionless factors referenced to the most toxic congeners (2,3,7,8-TCDD and 1,2,3,7,8-PentaCDD), which are arbitrarily assigned a value of 1 (Van den Berg and other, 1998). As a result, when TEQs are calculated, the resulting values are reported in concentration units (e.g., ppb). The concentration found for each congener in ppb is multiplied by its respective TEF value to obtain a TEQ value, also in the concentration units (e.g. ppb).

Congener	Humans/Mammals	Fish	Birds
1,2,3,4,6,7,8-HeptaCDF	0.01	0.01	0.01
1,2,3,4,7,8,9-HeptaCDF	0.01	0.01	0.01
OctaCDF	0.0001	<0.0001	0.0001
Dioxin-Like (Coplanar) PCB Congeners			
3,3',4,4'-TetraCB (PCB 77)	0.0001	0.0001	0.05
3,4,4',5-TetraCB (PCB 81)	0.0001	0.0005	0.1
2,3,3',4,4'-PentaCB (PCB 105)	0.0001	<0.000005	0.0001
2,3,4,4',5- PentaCB (PCB 114)	0.0005	<0.000005	0.0001
2,3',4,4',5- PentaCB (PCB 118)	0.0001	<0.000005	0.00001
2',3,4,4',5- PentaCB (PCB 123)	0.0001	<0.000005	0.00001
3,3',4,4',5-PentaCB (PCB 126)	0.1	0.005	0.1
2,3,3',4,4',5-HexaCB (PCB 156)	0.0005	<0.000005	0.0001
2,3,3',4,4',5'-HexaCB (PCB 157)	0.0005	<0.000005	0.0001
2,3',4,4',5,5'-HexaCB (PCB 167)	0.00001	<0.000005	0.00001
3,3',4,4',5,5'-HexaCB (PCB 169)	0.01	0.00005	0.001
2,3,3',4,4',5,5'-HeptaCB (PCB 189)	0.0001	<0.000005	0.00001

Abbreviations: **CDD** - chlorinated dibenzodioxins;
CDF - chlorinated dibenzofurans;
CB - chlorinated biphenyls

The current study uses these Toxicity Equivalence Factors (TEFs) to calculate the cumulative TEQs[38] (Toxic Equivalences) for CT River fish consumption by humans, mammals, birds, and fish.

EPA has produced a draft reassessment of dioxin and dioxin-like compounds that has proved highly controversial and thus has been released only in draft form, not to be cited or quoted. In the fall of 2004 the National Academy of Sciences was asked to peer review EPA's reassessment, the draft of which is publicly available: (http://www.epa.gov/ncea/pdfs/dioxin/nas-review/).

In recent years scientists have become aware of an "emerging contaminant issue" analogous to that of dioxins and PCBs, that of PBDEs (polybrominated diphenyl ethers). PBDEs are widely used as fire retardants in furniture, carpeting, automobiles and computers, among other uses. PBDE industrial use has increased dramatically since the 1970s, as have the observed levels in biological 'compartments', including fish tissue and mother's milk (Fields 2005). The biological effects of PBDEs on humans are not well understood, however, in animals researchers have documented "effects similar to those of PCBs, including effects on brain development, learning, memory, thyroid levels, and reproduction" (Fields 2005:A169). PBDE levels have been increasing exponentially in Great Lakes fish over the last 10–15 years, with no sign of decrease in this trend. Schantz (2005: A138) observes "[T]his buildup is of particular concern because of the potential for additive effects from combined exposure to PBDEs and their close chemical cousins, the PCBs."

Monitoring of PBDEs, however, is still expensive and complex, being done by only a few laboratories and thus the extent of this problem, as for dioxin, is poorly characterized. EPA's National Fish Tissue Study will analyze the 2004 samples for these contaminants, providing some indication of their extent and severity.

In the CT River fish tissue study observed concentrations of dioxins and dioxin-like PCBs in whole and filleted smallmouth bass, yellow perch and white suckers were normalized to the WHO toxicity estimates shown in Table 22, allowing calculation of Toxic Equivalences (TEQs). TEQs were displayed graphically, compared statistically, and assessed for their toxicity to human, mammalian, bird, and fish receptors.

Carcinogenic human health screening values are from USEPA (2000a) *Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories - Third Edition,*

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[38] Definition of TEQs: http://c3.org/sitedata/test3/def.html; http://www.ecoinfo.ec.gc.ca/env_ind/region/dioxinfuran/defndioxin_e.cfm#WHO

Volume 1: Fish Sampling and Analysis (Table 23)[39]. Eco-risk screening values are from EPA's (1993) *Interim Report on Data and Methods for Assessment of 2,3,7,8-TCDD Risks to Aquatic Life and Associated Wildlife* (Table 24).

Table 23. EPA Human Health Carcinogenic Screening Values (CSVs) for Coplanar PCB and Dioxin TEQs in Fish Tissue (USEPA 2000a)

Human Health Carcinogenic Screening Values (CSV) (ppb)	
Recreational Fishers	Subsistence Fishers
2.56E-04	3.15E-05

Table 24. EPA Low and High Eco-Risk Screening Values for Fish-eating Mammals, Birds and Fish exposure to Coplanar PCB and Dioxin TEQs (USEPA 1993)

Fish-eating Wildlife Receptor	**Fish Concentration (ppb)**
Low Eco-Risk	
Mammals	7.00E-04
Birds	6.00E-03
Fish	5.00E-02
High Eco-Risk	
Mammals	7.00E-03
Birds	6.00E-02
Fish	8.00E-02

[39]EPA (2000a) uses a risk level of 10^{-5} for carcinogenic endpoint screening which corresponds to an estimated risk of 1:100,000 of acquiring cancer from a life time's exposure at this level. It is the middle of EPA's acceptable cancer risk range.

3.2 Human Health and Eco-Risk Screening for Dioxin/Furan and Coplanar PCB TEQs in Fillets

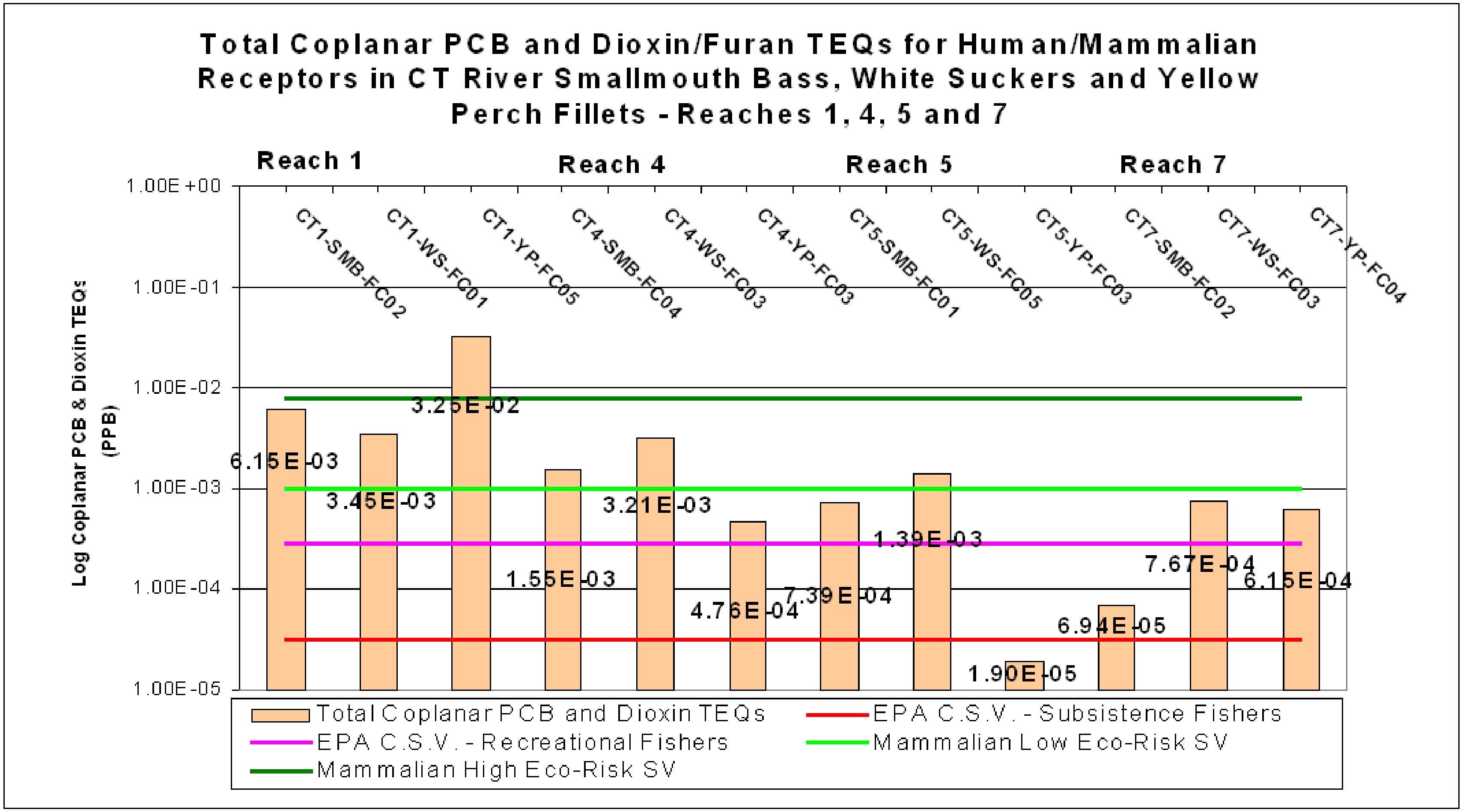

Figure 41. Log_{10} Total Coplanar PCB and Dioxin/Furan TEQs for Human/Mammalian Receptors in CT River Smallmouth Bass, White Suckers and Yellow Perch Fillets - Reaches 1, 4, 5 and 7

Only 12 fish fillets, no whole fish, were analyzed for dioxins, because of the cost of this complex analysis. Figure 41 shows the total coplanar PCB and dioxin TEQ risk for humans and mammals, compared to the carcinogenic screening value (CSV) for recreational and subsistence fishers and low and high mammalian eco-risk SVs, although mammals do not eat fillets. Ten of twelve fillets exceeded both human CSVs. Only one YP fillet from Reach 5 didn’t exceed either human threshold. One SMB fillet in Reach 7 only exceeded the subsistence fisher CSV. A gradient of lower TEQ values in upper Reaches is suggested from this very small data set.

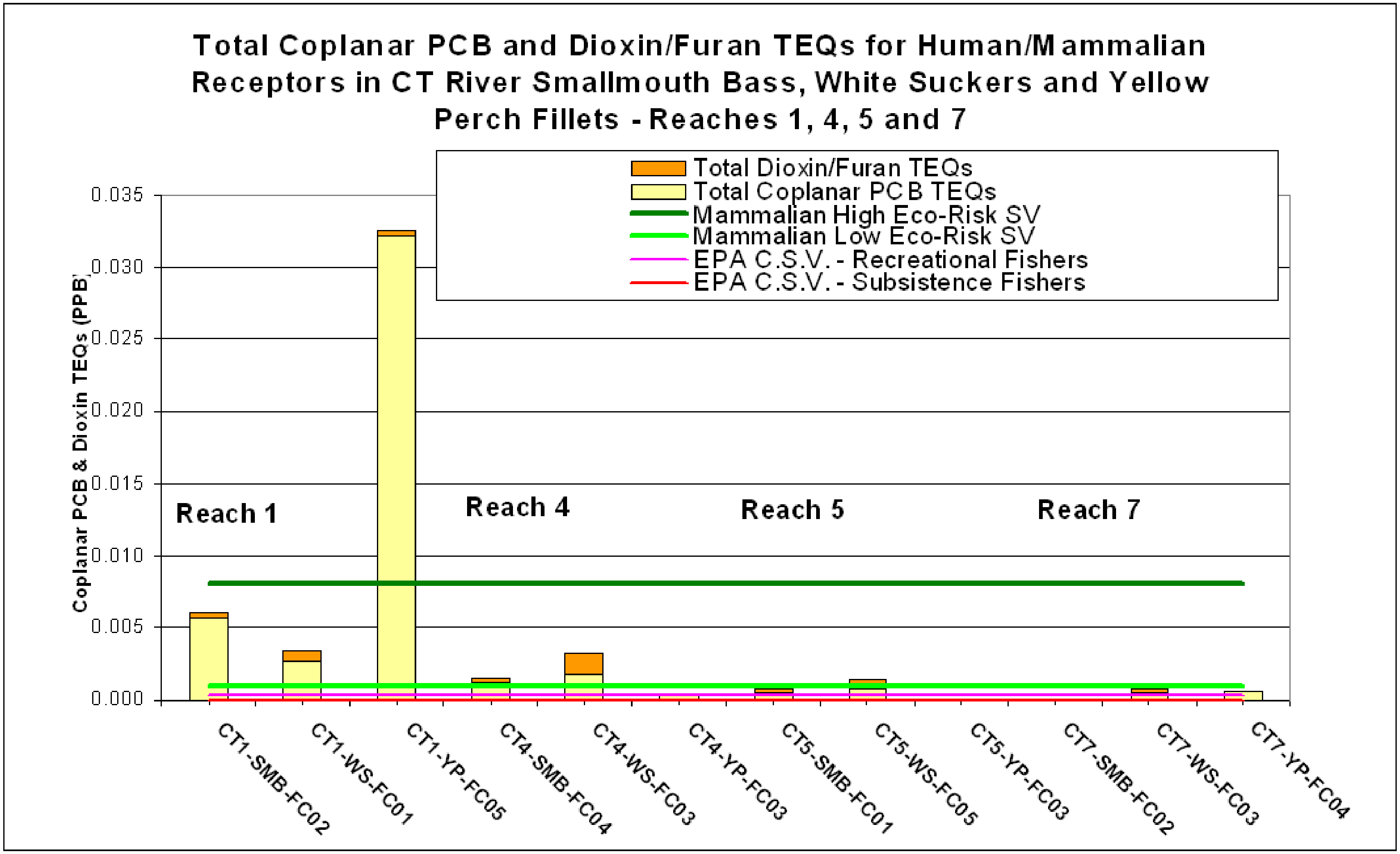

Figure 42. Linear Total Coplanar PCB and Dioxin/Furan TEQs for Human/Mammalian Receptors in CT River Smallmouth Bass, White Suckers and Yellow Perch Fillets - Reaches 1, 4, 5 and 7

Figure 42 graphs the same data as Figure 41, except the Y axis is linear, not log and the relative contribution of coplanar PCBs and dioxins is shown. Note that dioxin contributes a highly variable proportion of the total TEQ toxicity (Figure 43).

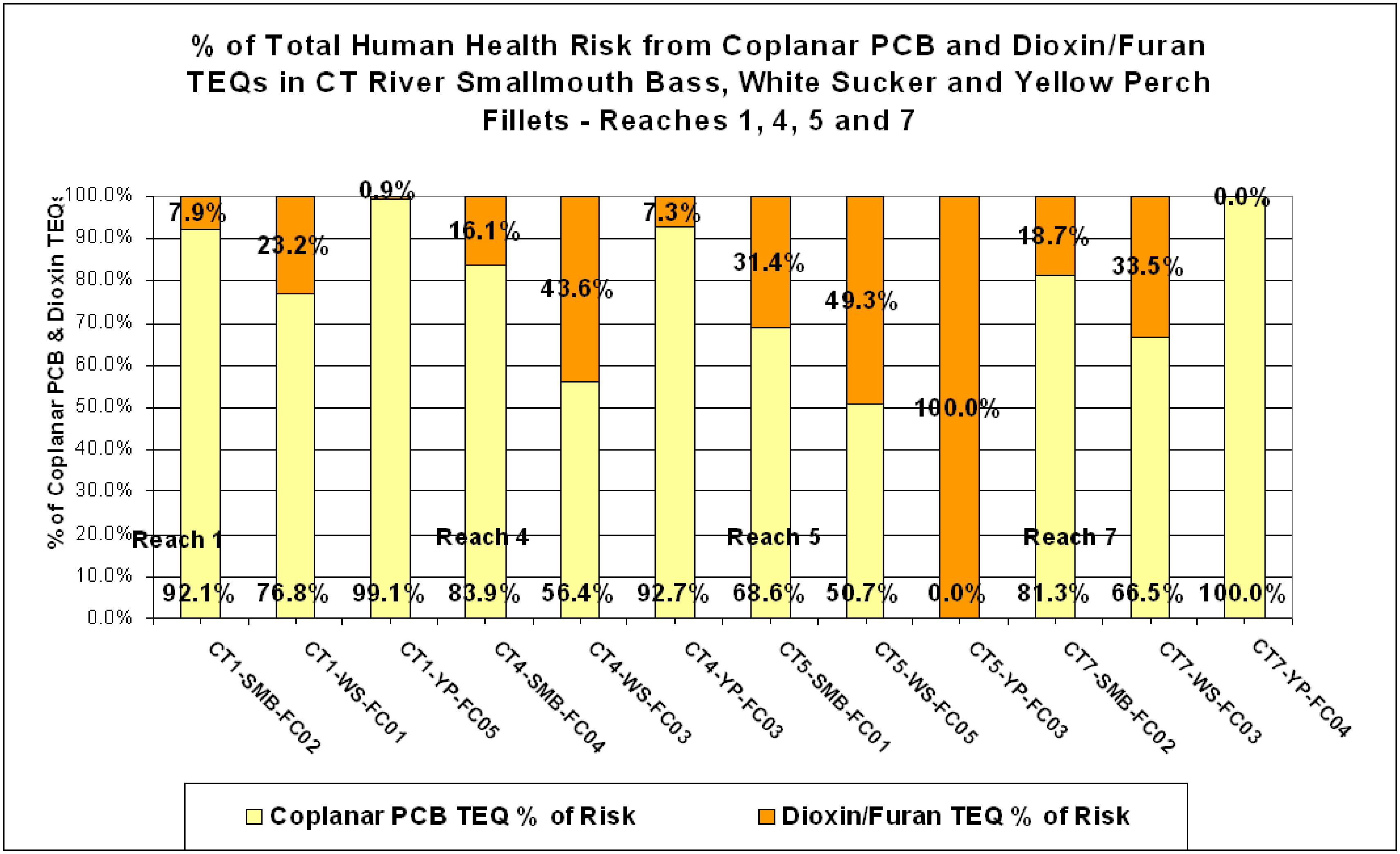

Figure 43. Percent of Total Human Health Risk from Coplanar PCB and Dioxin/Furan TEQs in CT River Smallmouth Bass, White Sucker and Yellow Perch Fillets - Reaches 1, 4, 5 and 7

Figure 43 shows the percent of total human health risk from coplanar PCB TEQs and dioxin TEQs in twelve CT River fish fillets. In all but one yellow perch fillet from Reach 7, in which no dioxins were detected, from 0.9% to 100% of the total human health risk is provided by dioxin TEQs, strongly suggesting that coplanar PCB TEQ risk, when dioxin TEQs are excluded from the risk calculation, may underestimate the risk from consumption of CT River fish. Dioxin risk appears to be highly variable in CT River fish and given this variability the magnitude of the human health and eco-risk can not be assessed with such a small sample.

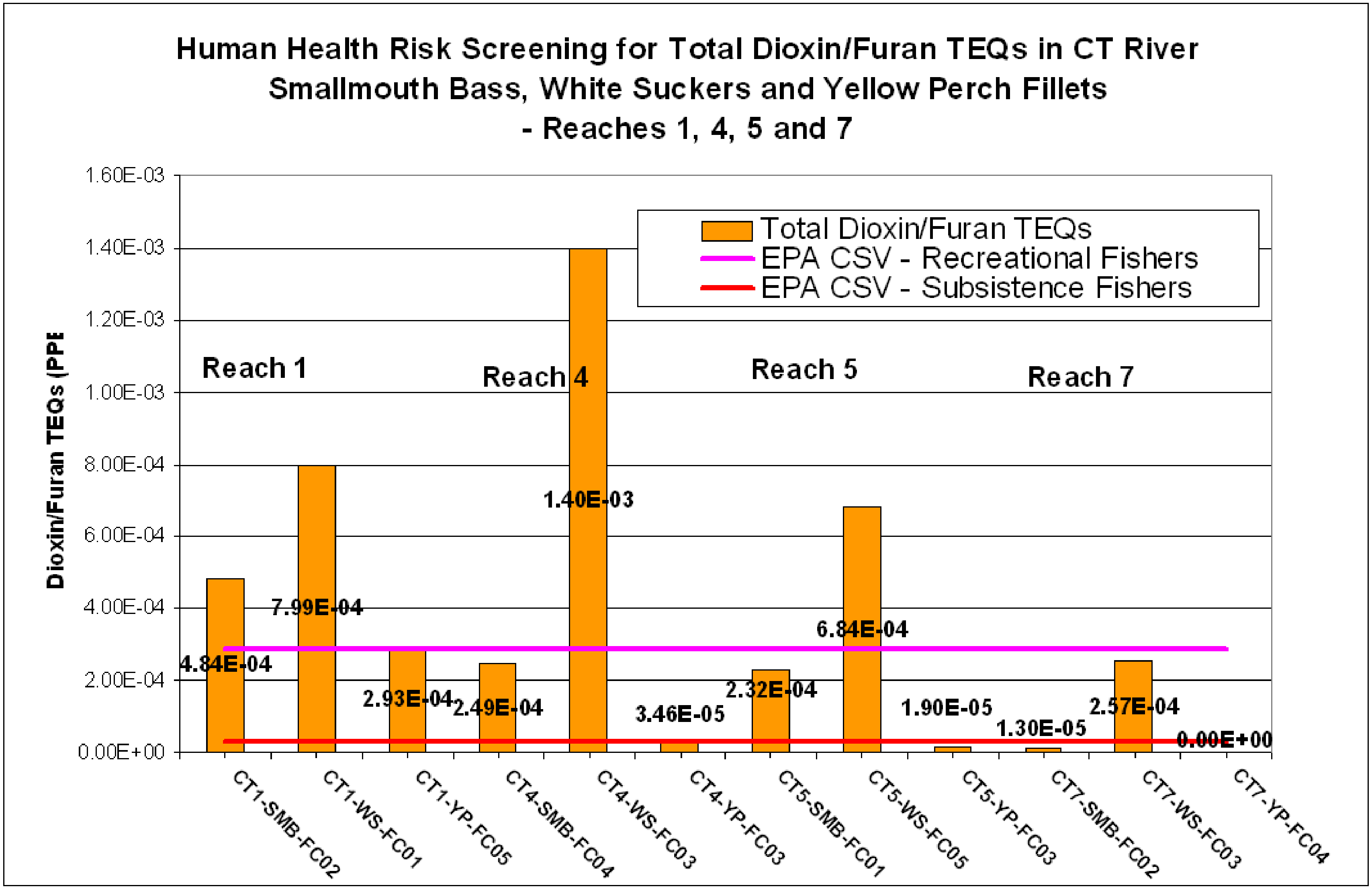

Figure 44. Human Health Risk Screening for Total Dioxin/Furan TEQs in CT River Smallmouth Bass, White Suckers and Yellow Perch Fillets - Reaches 1, 4, 5 and 7

Figure 44 shows only the dioxin/furan TEQ toxicity with human recreational and subsistence fisher CSVs. Dioxin/furan TEQs, even when coplanar TEQ toxicity is not included, still pose a sizeable risk to recreational and subsistence fishers.

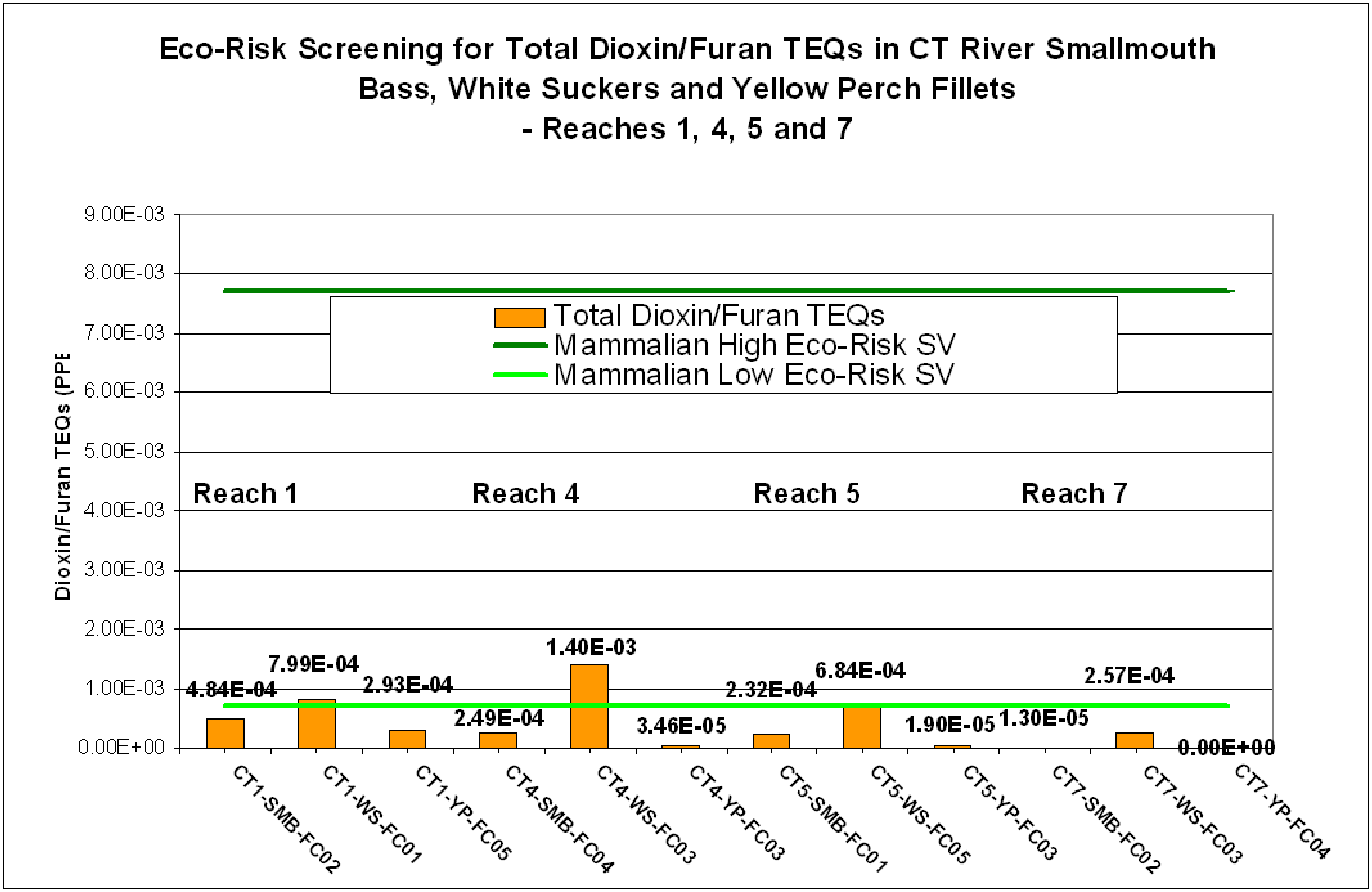

Figure 45. Eco-Risk Screening for Total Dioxin/Furan TEQs in CT River Smallmouth Bass, White Suckers and Yellow Perch Fillets - Reaches 1, 4, 5 and 7

Figure 45 shows the same data as Figure 44, except the mammalian eco-risk SVs are shown. Although mammals do not eat fillets, it is clear that dioxin/furan TEQs in whole fish would pose a greater eco-risk to mammals.

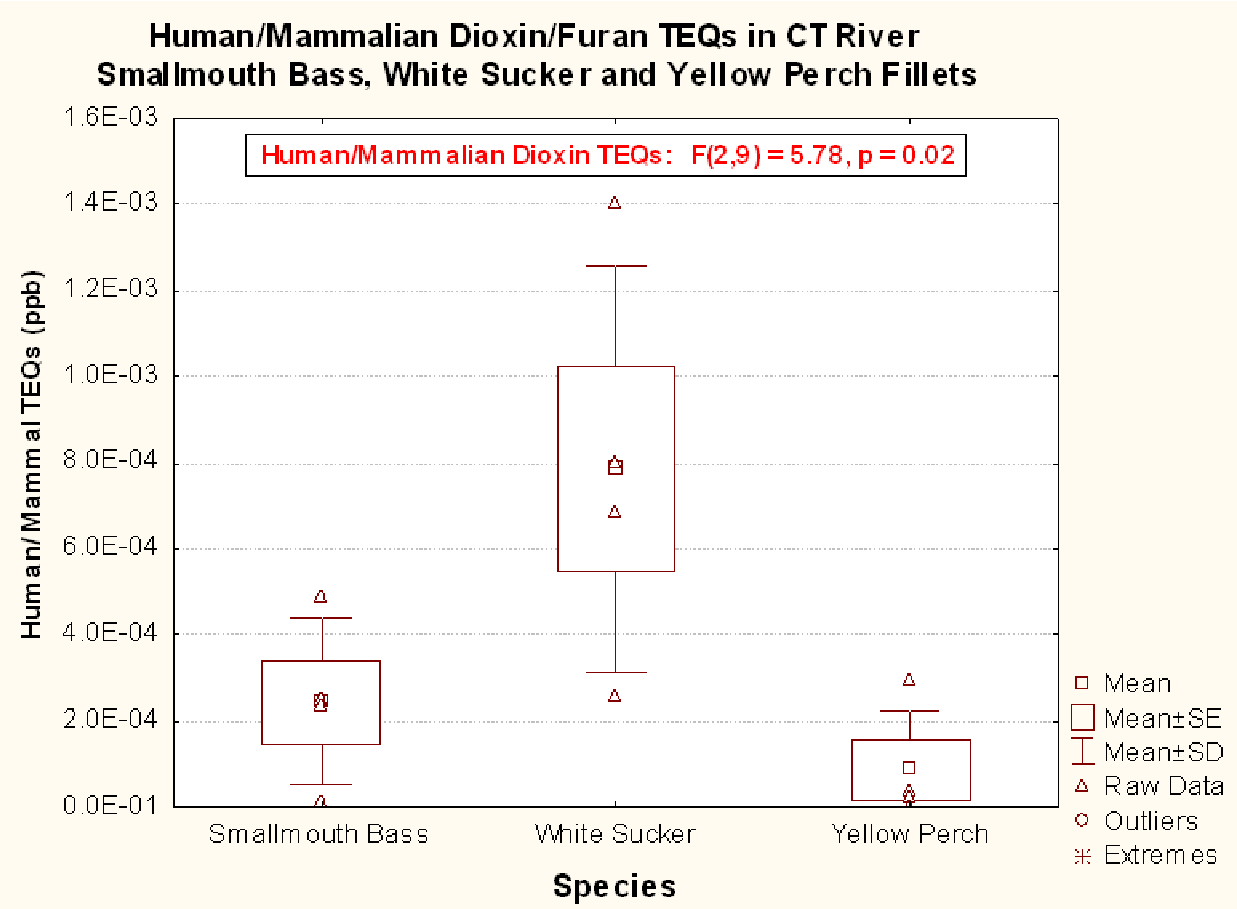

Figure 46. Human/Mammalian Dioxin/Furan TEQs in CT River Smallmouth Bass, White Sucker and Yellow Perch Fillets

Figure 46 shows box plots of human/mammalian dioxin/furan TEQs for smallmouth bass, white sucker, and yellow perch fillets. An ANOVA found a significant difference between species. White suckers (LS Mean = 7.85E-04) were significantly higher than either smallmouth bass (LS Mean = 2.44E-04) or yellow perch (LS Mean = 8.66E-05). No significant difference was found between smallmouth bass and yellow perch (F(1, 6)=1.7773, p=.23087 p=0.23). The observed mean smallmouth bass fillet dioxin TEQ is approximately 16% of that observed in smallmouth bass fillets in EPA's 1992 National Study of Chemical Residues in Fish (USEPA 1992a; 1992b), based on WHO consensus TEQs (Table 22)[40].

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[40]The 1992 report and the EPA (2000a) reprint of that data calculated TEQs based on Barnes and Bellin (1989), EPA's previous TEF standard.

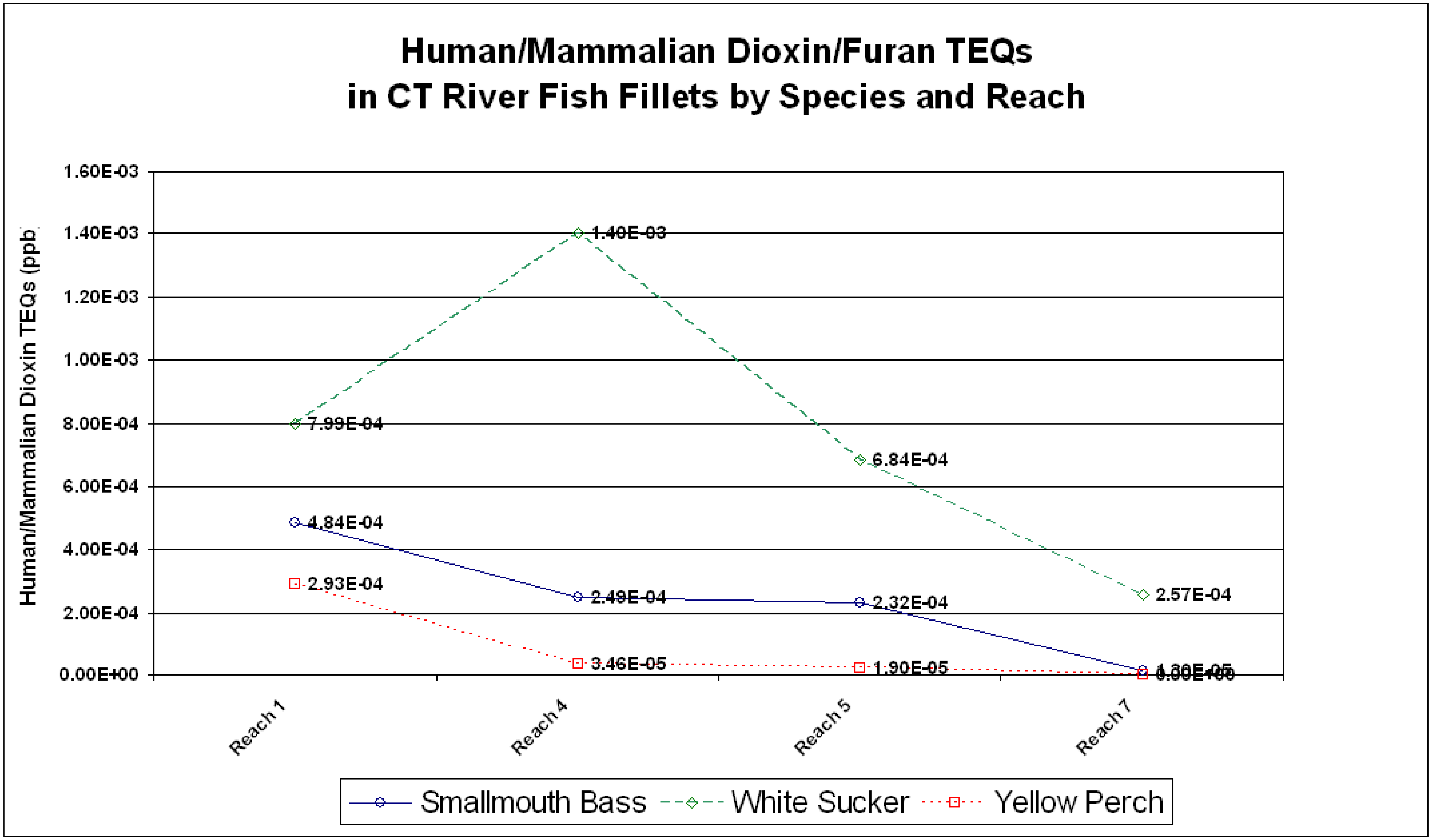

Figure 47. Human/Mammalian Dioxin/Furan TEQs in CT River Fish Fillets by Species and Reach

Figure 47 shows the observed human/mammalian dioxin/furan TEQs in CT River smallmouth bass, white suckers, and yellow perch by Reach.

3.3 Coplanar PCB TEQs - Human Health and Mammalian Eco-Risk Screening
3.3.1 Coplanar PCB TEQs - Human Health and Mammalian Eco-Risk Screening - Whole Fish

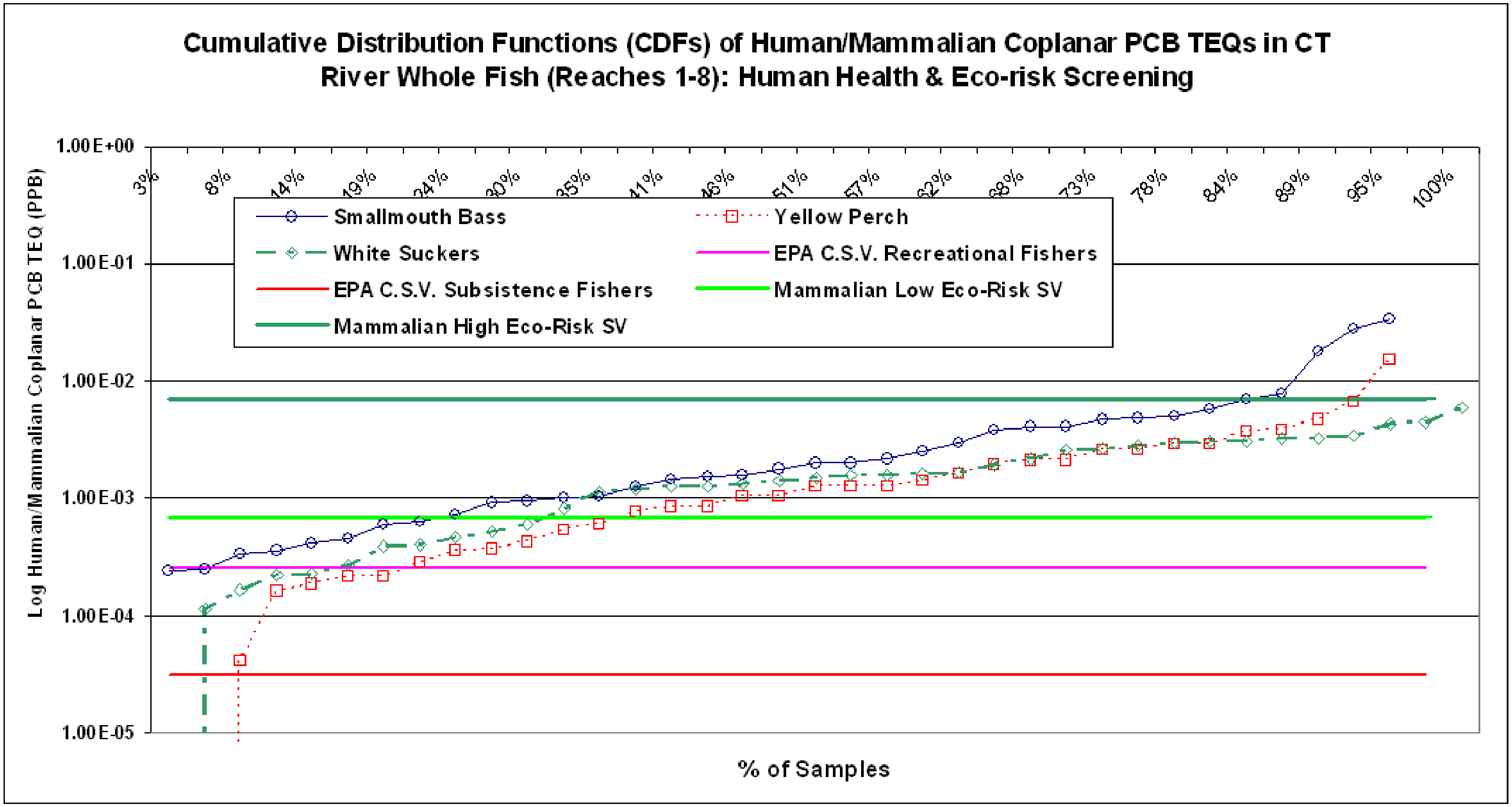

Figure 48. CDFs of Human/Mammalian Coplanar PCB TEQs in CT River Whole Fish (Reaches 1-8): Human Health and Eco-Risk Screening

All whole fish in Figure 48 exceeded the CSV for subsistence fishers. 98% of whole smallmouth bass, 80% of whole yellow perch and 86% of whole white suckers exceeded the CSV for recreational fishers, many by several orders of magnitude (note the log10 scale)(Table 23). Samples graphed below 1.0E-05 had no coplanar PCB TEQs detected. Clearly some differences in human/mammalian receptor coplanar PCB TEQs are found among the three species of CT River whole fish, with smallmouth bass having the highest levels. 77% of SMB, 63% of YP and 70% of WS exceeded the low eco-risk SV. Only 14% of SMB, 3% of YP and no WS exceeded the high eco-risk SV. Thus CT River fish-eating mammals are potentially at risk from coplanar PCB TEQs.

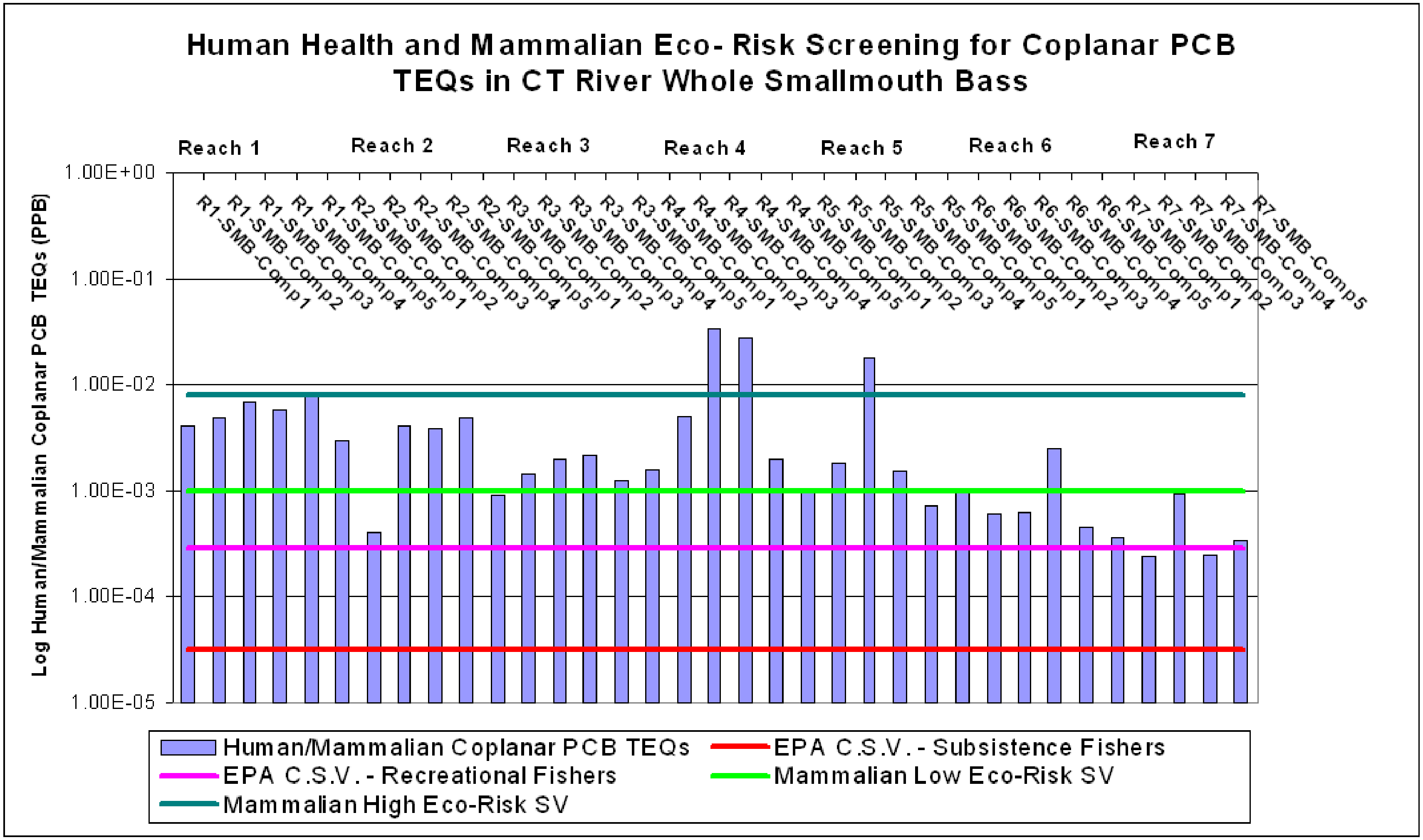

Figure 49. Human Health and Mammalian Eco-Risk Screening for Coplanar PCB TEQs in CT River Whole Smallmouth Bass

Figure 49 compares the coplanar PCB TEQs in whole smallmouth bass with EPA carcinogenic screening levels (CSVs) for recreational and subsistence fishers and the EPA screening levels (SL) for mammals. All samples exceeded the human health screening levels for subsistence fishers and 98% exceeded that for recreational fishers. 77% of whole SMB exceeded the low eco-risk SV and 14% exceeded the high eco-risk SV. All whole SMB had detected TEQ toxicity.

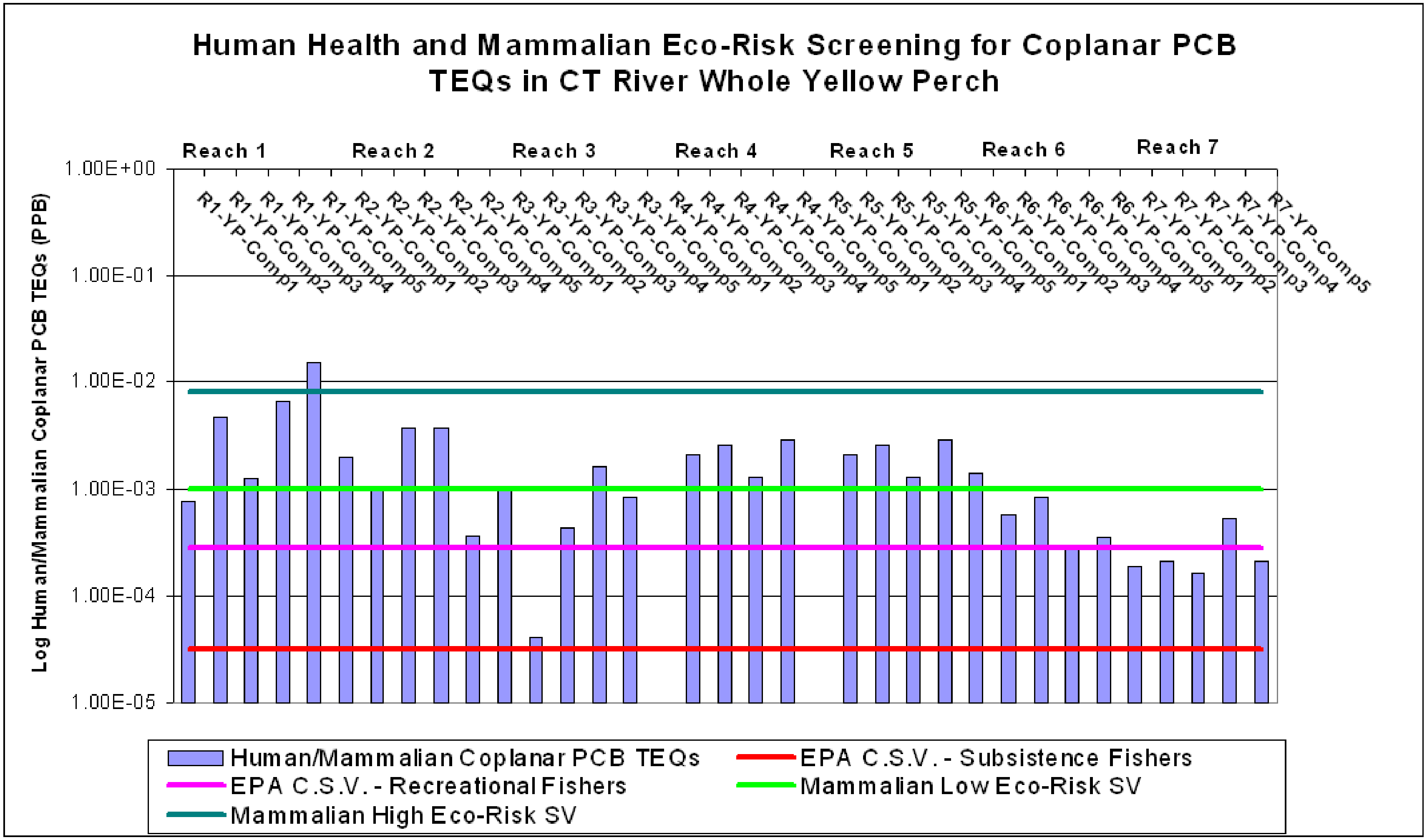

Figure 50. Human Health and Mammalian Eco-Risk Screening for Coplanar PCB TEQs in CT River Whole Yellow Perch

Figure 50 compares the coplanar PCB TEQs in whole yellow perch with EPA CSVs for recreational and subsistence fishers and the EPA screening level (SL) for mammals. All samples exceeded the human health screening levels for subsistence fishers and 80% exceeded that for recreational fishers. 29% of whole YP exceeded the low eco-risk SV and 3% exceeded the high eco-risk SV for fish-eating (piscivorous) mammals. One YP whole fish sample each in Reaches 4 and 5 had no detected human/mammalian TEQ toxicity.

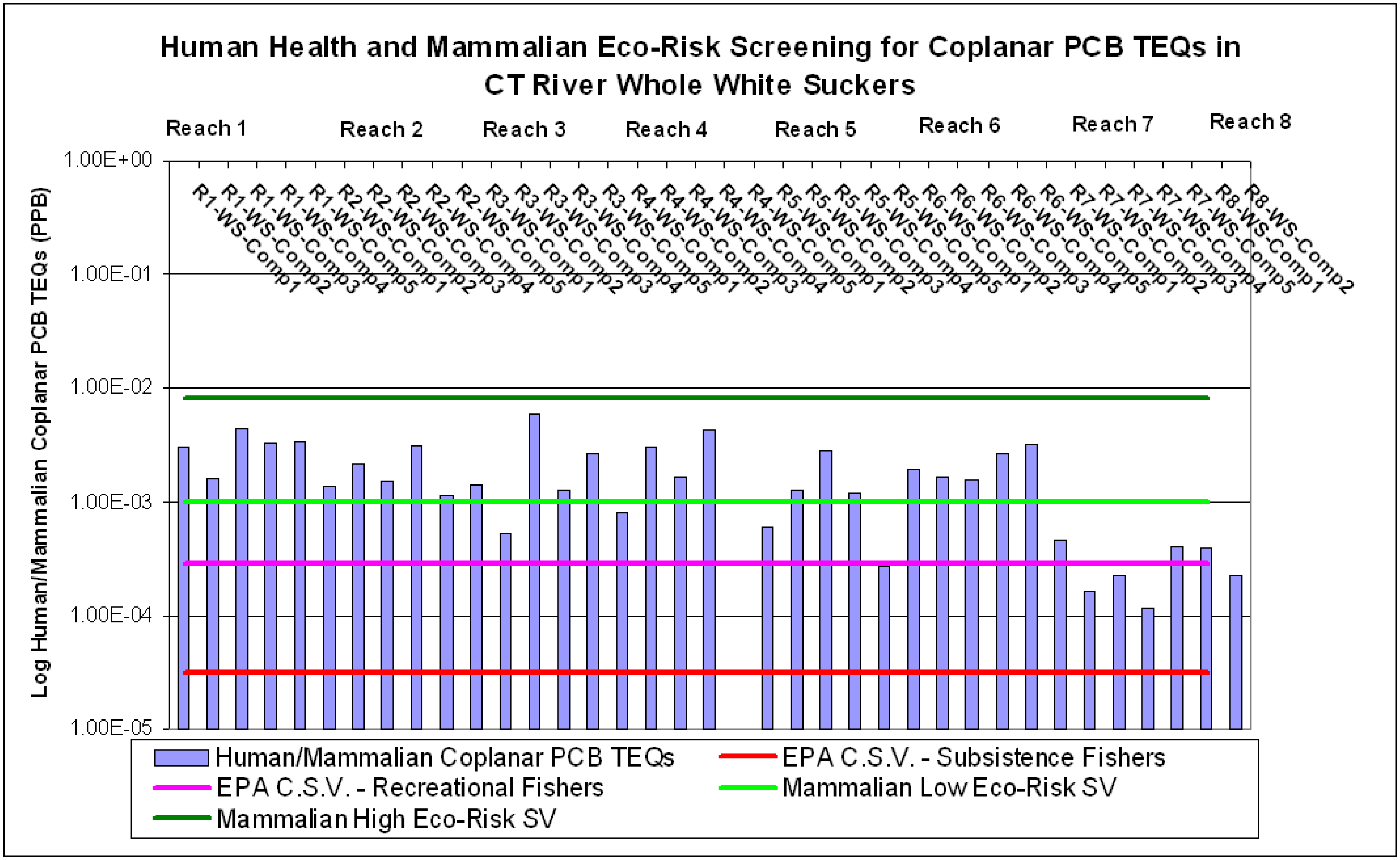

Figure 51. Human Health and Mammalian Eco-Risk Screening for Coplanar PCB TEQs in CT River Whole White Suckers

Figure 51 compares the coplanar PCB TEQs in whole white suckers with EPA CSVs for recreational and subsistence fishers. All samples exceeded the CSV for subsistence fishers and 86% exceeded that for recreational fishers. 49% of whole WS exceeded the low eco-risk SV, while none exceeded the high eco-risk SV for fish-eating mammals. Only one WS whole fish sample in Reach 4 had no detected TEQ toxicity.

3.3.2 Coplanar PCB TEQs - Human Health Risk Screening - Fillets

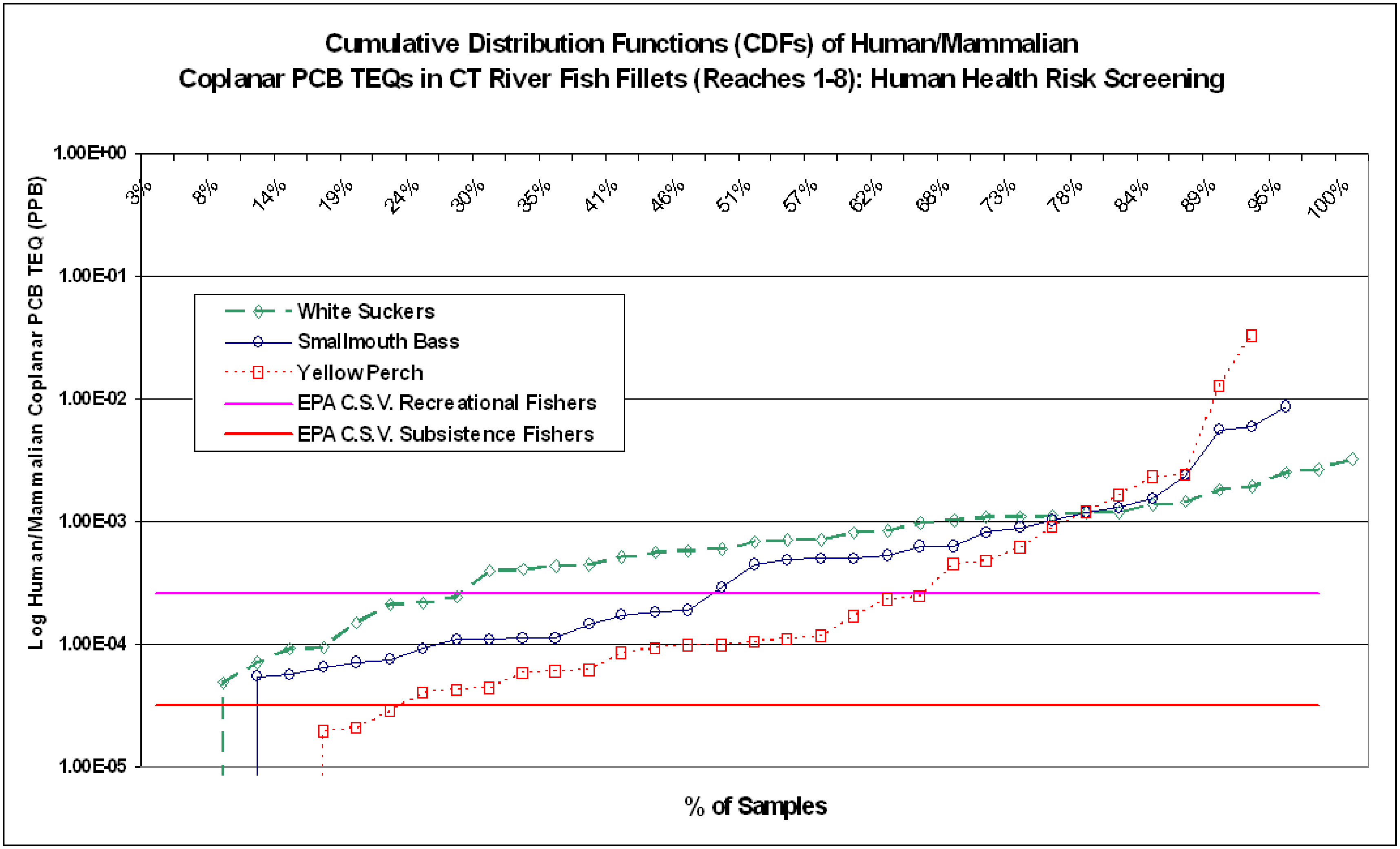

Figure 52. CDFs of Human/Mammalian Coplanar PCB TEQs in CT River Fish Fillets (Reaches 1-8): Human Health Risk Screening

Figure 52 shows the CDFs for human/mammalian coplanar PCB TEQs in fish fillets. 100% of smallmouth bass and white sucker fillets and 86.5% of yellow perch fillets exceeded the EPA carcinogenic screening value (CSV) for subsistence fishers. 51.4% of smallmouth bass, 29.4% of yellow perch and 73% of white sucker fillets exceeded the EPA C.S.V. for recreational fishers (Table 23). Samples graphed below 1.0E-05 had no coplanar PCB TEQs detected. The pattern between species for fillet samples was different than for whole fish.

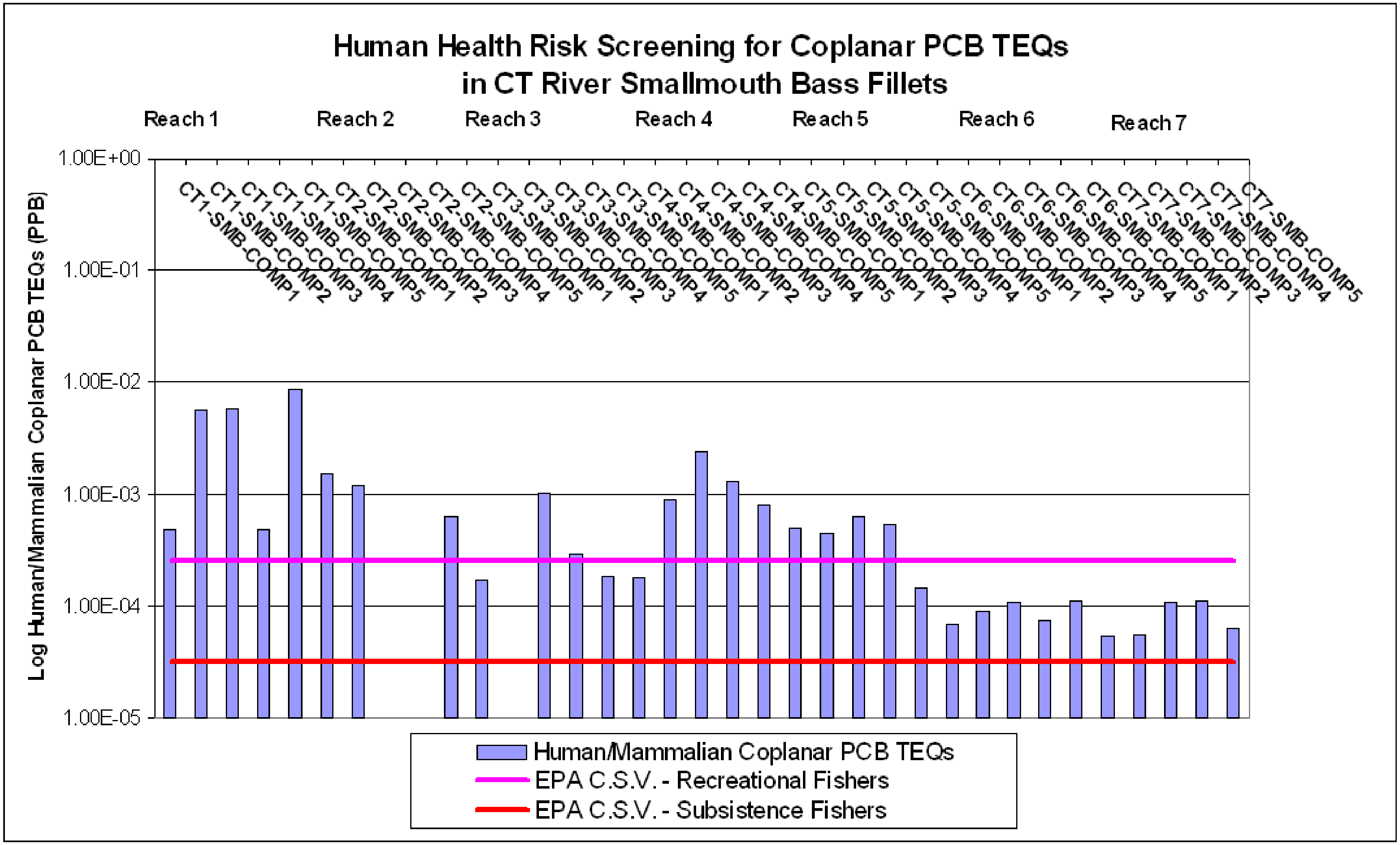

Figure 53. Human Health Risk Screening for Coplanar PCB TEQs in CT River Smallmouth Bass Fillets

Figure 53 compares the coplanar PCB TEQs in CT River smallmouth bass fillets to CSVs (Carcinogenic Screening Values) for recreational and subsistence fishers. 93% of SMB fillets exceeded the CSV for subsistence fishers. 51% of the smallmouth bass fillets exceeded the CSV for recreational fishers. Three fillets had no detectable levels of coplanar TEQs. Lower levels were observed in higher Reaches. See the next section for parametric statistical analysis of the CT River fish coplanar PCB TEQ data.

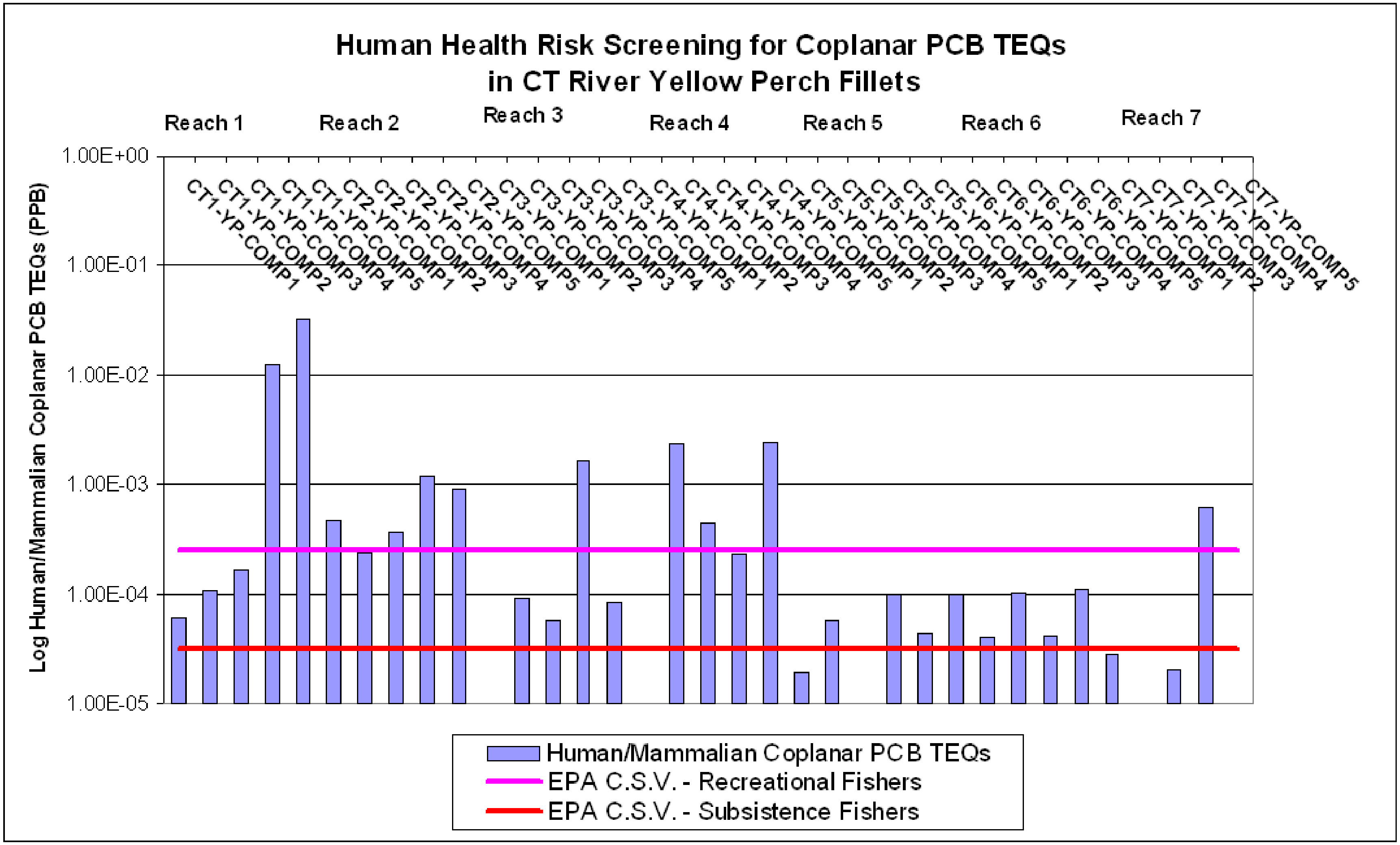

Figure 54. Human Health Risk Screening for Coplanar PCB TEQs in CT River Yellow Perch Fillets

In Figure 54 76% of yellow perch fillet composites exceeded the CSV for subsistence fishers. 29% exceeded the recreational fisher CSV. 5 YP fillets had no detectable levels of coplanar PCB TEQs. Generally lower levels observed in Reaches 5, 6, and 7 may reflect a true geographic gradient (trend) or may be a statistical anomaly. See the next section for parametric statistical analysis of the CT River fish coplanar PCB TEQ data.

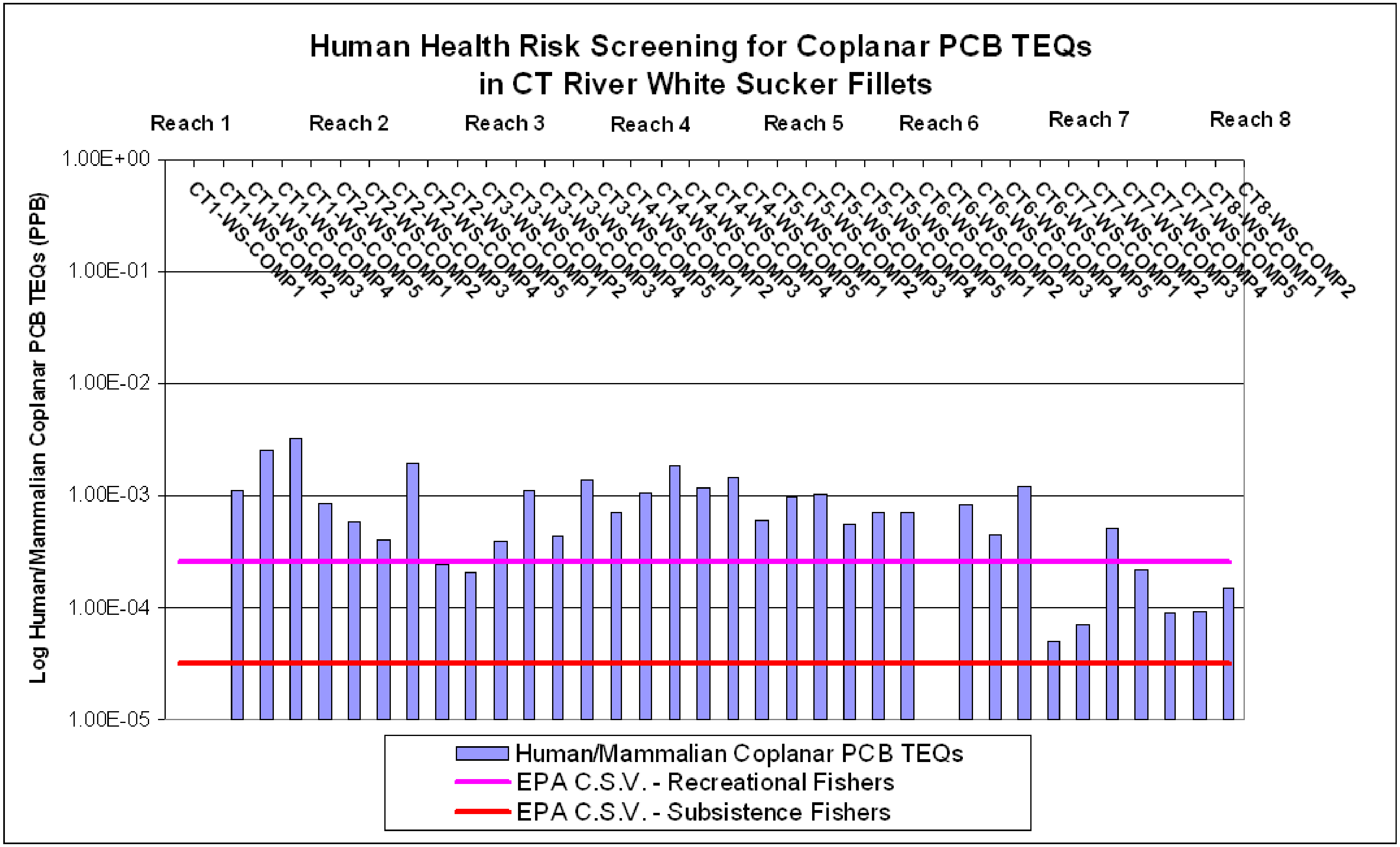

Figure 55. Human Health Risk Screening for Coplanar PCB TEQs in CT River White Sucker Fillets

In Figure 55 95% of white sucker fillets exceeded the CSV for subsistence fishers and 73% exceeded the CSV for recreational fishers. Two fillets had no detectable levels of coplanar PCB TEQs. The next section of this report provides Reach by Reach statistical comparison observed coplanar PCB TEQs.

3.4 Coplanar PCB TEQ - Piscivorous (Fish-eating) Bird Eco-Risk Screening - Whole Fish

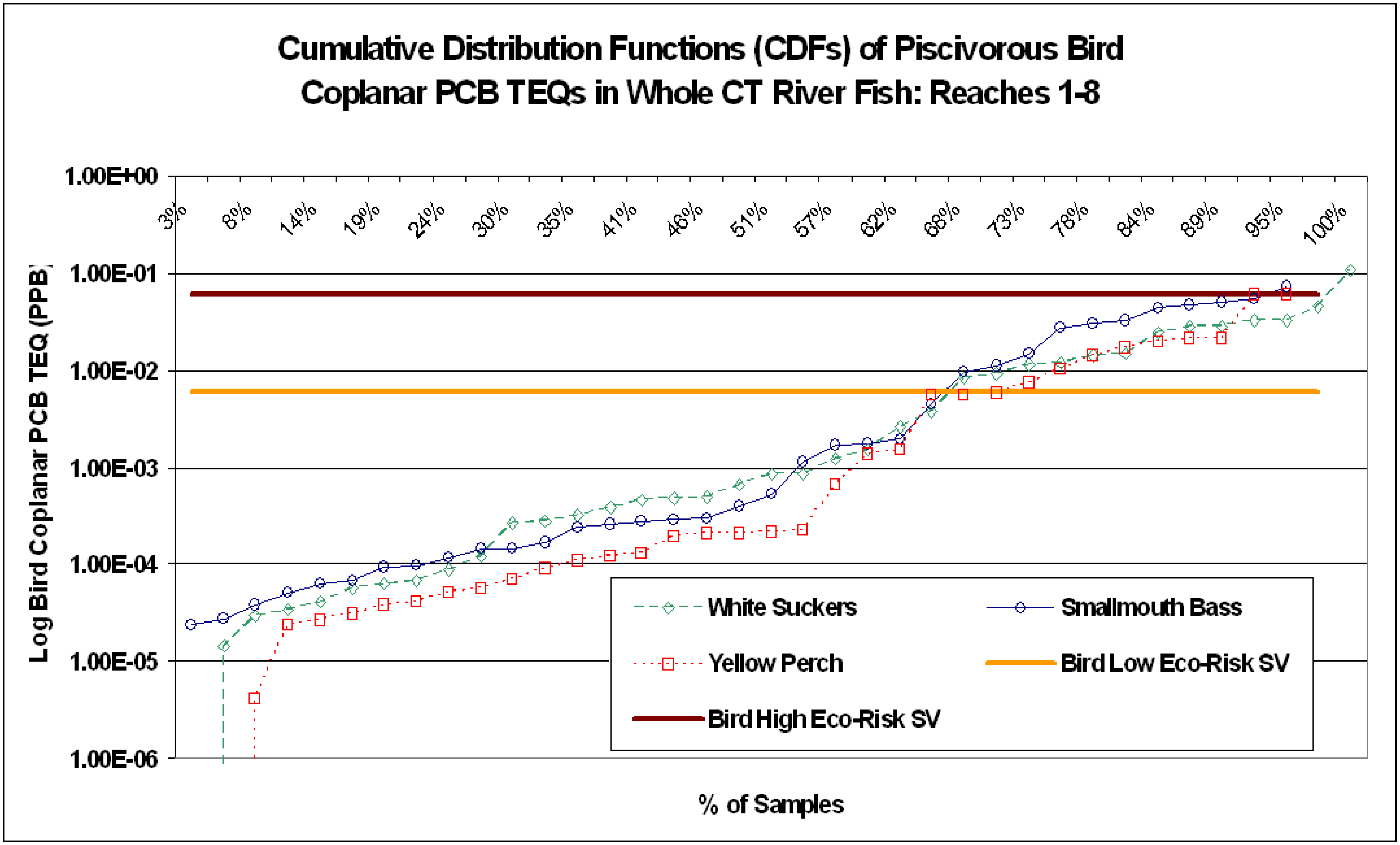

Figure 56. CDFs of Piscivorous Bird Coplanar PCB TEQs in Whole CT River Fish: Reaches 1-8

Figure 56 shows that 31% of SMB, 26% of YP and 35% of whole WS exceeded the low eco-risk SV for piscivorous birds (Table 25). Only one SMB and WS and no YP exceeded the high eco-risk SV. A single sample from Reach 4 accounts for the observed "upturn" in the distribution of fish-eating bird receptor TEQs for whole white suckers. One WS and two YP had no detectable bird coplanar PCB TEQ toxicity.

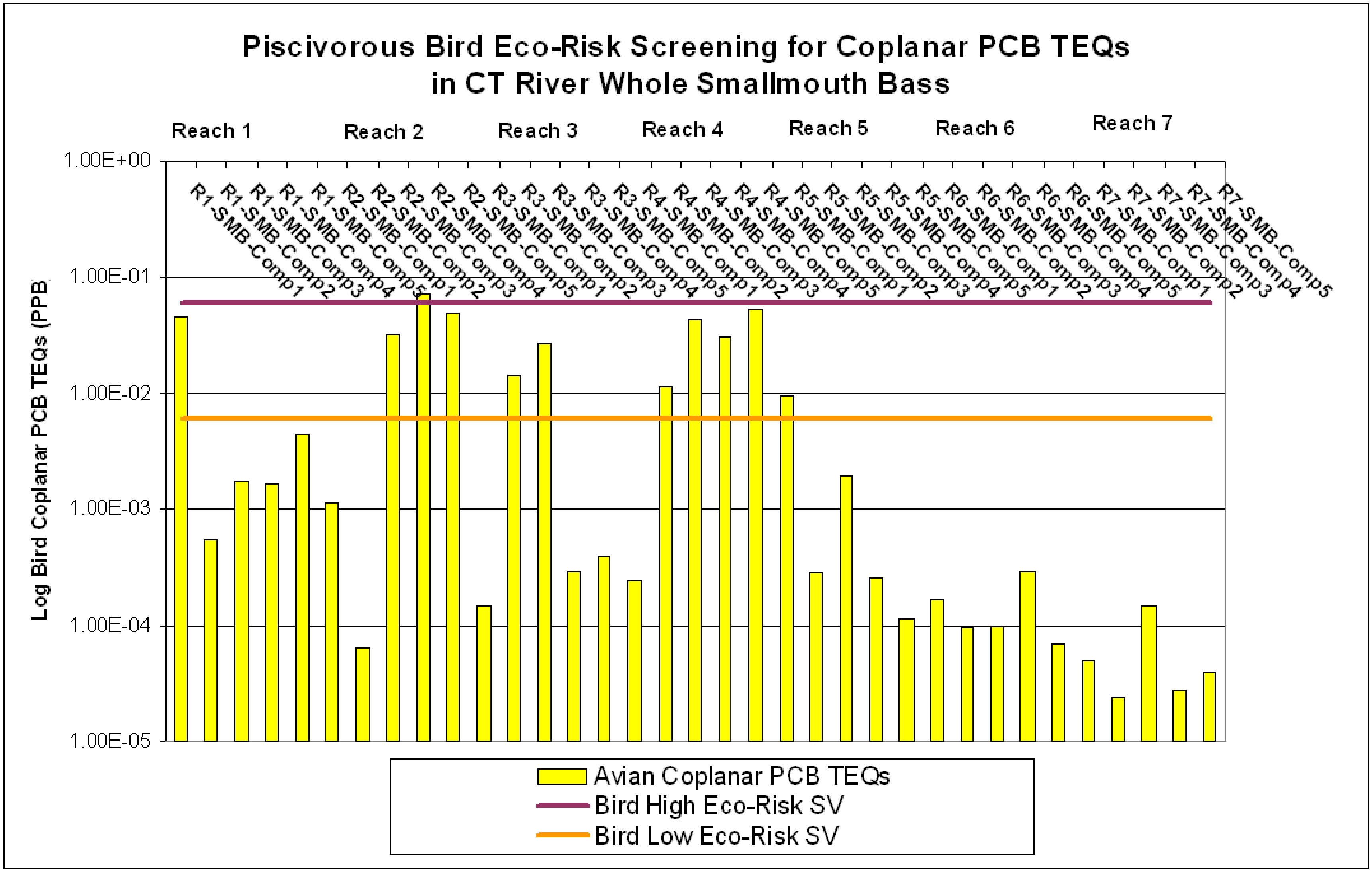

Figure 57. Piscivorous Bird Eco-Risk Screening for Coplanar PCB TEQs in CT River Whole Smallmouth Bass

Figure 57 shows that 31% of whole smallmouth bass exceeded the low eco-risk SV and a single SMB exceeded the high eco-risk SV. Lower levels of fish-eating bird coplanar PCB TEQs were observed in Reaches 5, 6, and 7. See the next section for parametric statistical comparison by Reach of the CT River fish coplanar PCB TEQ data.

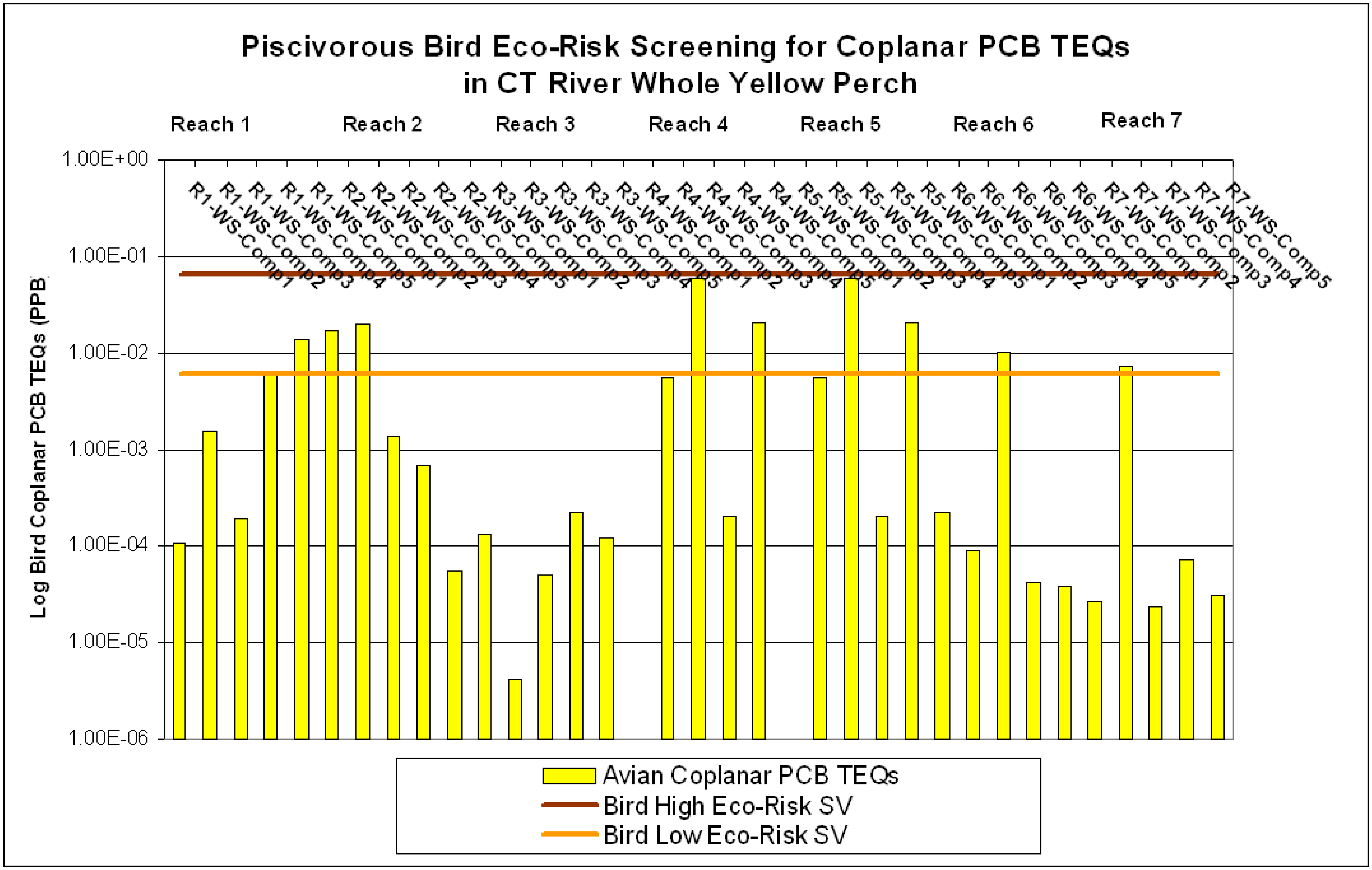

Figure 58. Piscivorous Bird Eco-Risk Screening for Coplanar PCB TEQs in CT River Whole Yellow Perch

Figure 58 shows that 26% of whole yellow perch exceeded the low eco-risk SV for fish-eating birds and no YP exceeded the high eco-risk SV. Two whole YP had no detectable coplanar PCB TEQs for fish-eating birds. Also, no clear geographic gradient was evident in the yellow perch coplanar PCB TEQ data.

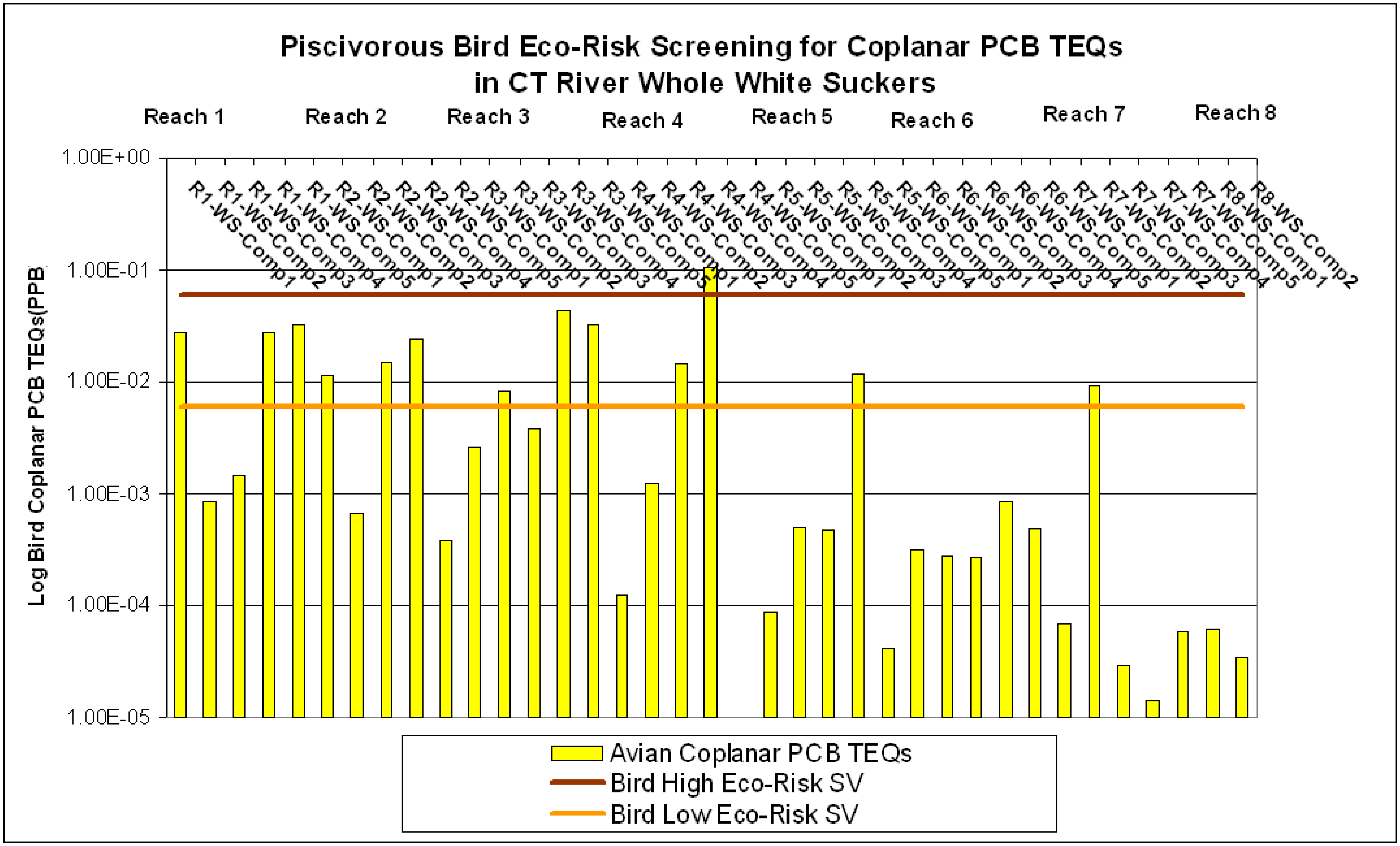

Figure 59. Piscivorous Bird Eco-Risk Screening for Coplanar PCB TEQs in CT River Whole White Suckers

Figure 59 shows that 35% of whole WS exceeded the low eco-risk SV for fish-eating birds, while only one sample (3%) exceeded the high eco-risk SV. One sample from Reach 4 had no detectable fish-eating bird coplanar PCB toxicity. Generally lower levels of coplanar PCB TEQs were observed in “upper” Reaches 5, 6 and 7. See the next section for parametric statistical analysis of the CT River fish coplanar PCB TEQ data.

3.5 Coplanar PCB TEQs - Piscivorous (Fish-eating) Fish Eco-Risk Screening - Whole Fish

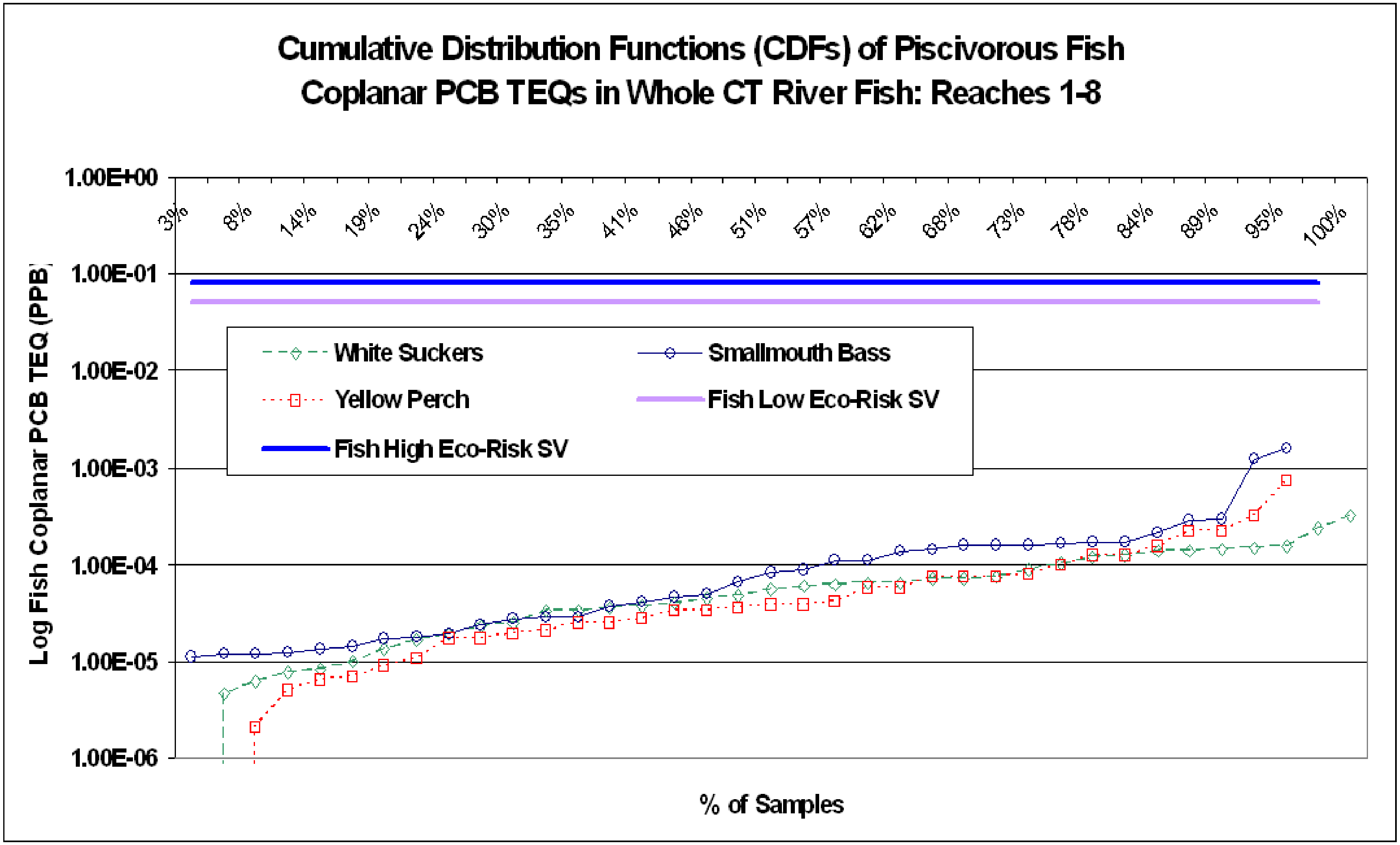

Figure 60. CDFs of Piscivorous Fish Coplanar PCB TEQs in Whole CT River Fish: Reaches 1-8

Figure 60 shows a similar pattern to that of fish-eating (piscivorous) bird receptor PCB TEQs (Table 25). No samples approached either fish eco-risk SV. Two yellow perch and one white sucker had no detectable piscivorous (fish-eating) fish coplanar PCB TEQ toxicity.

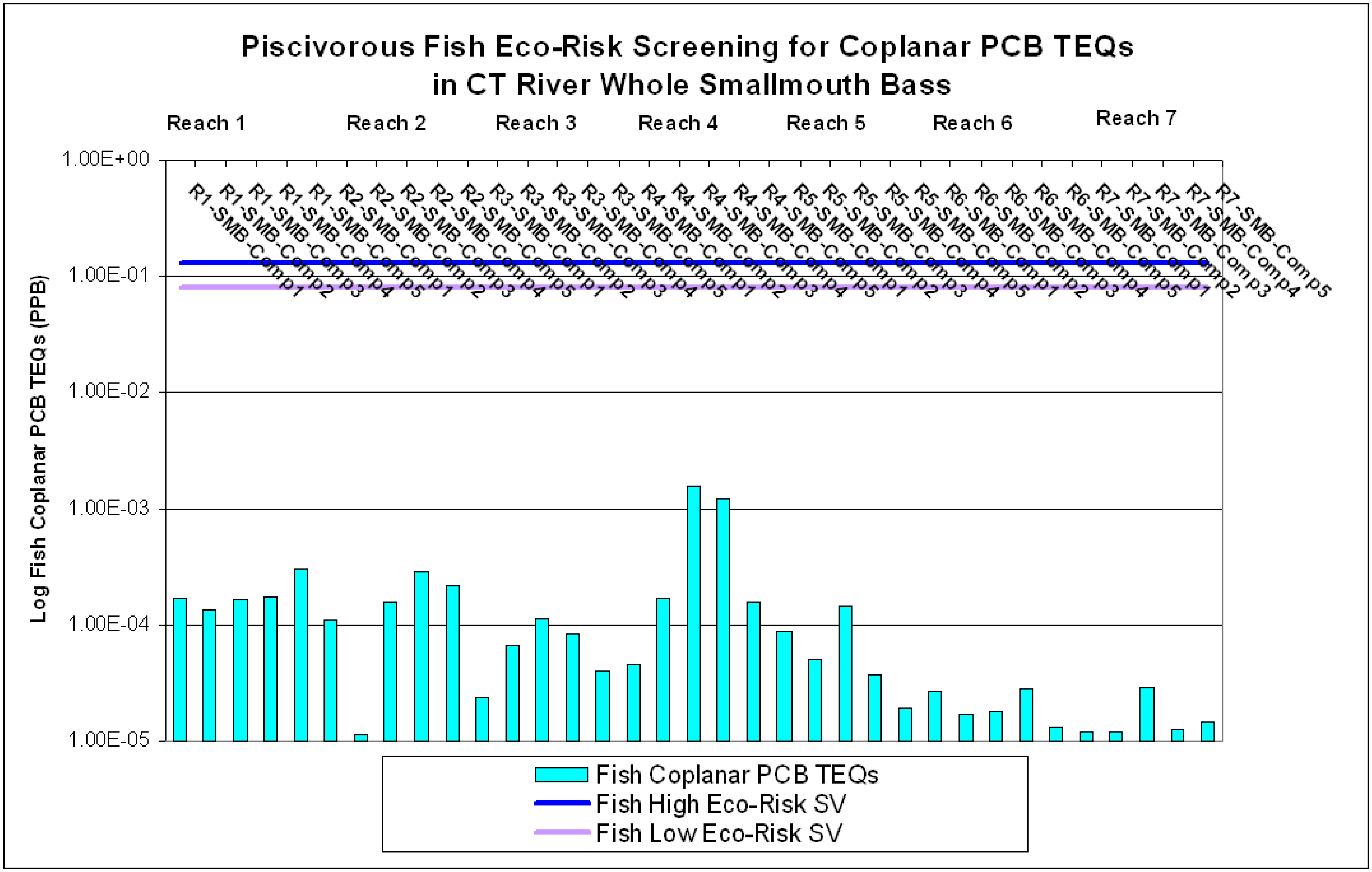

Figure 61. Piscivorous Fish Eco-Risk Screening for Coplanar PCB TEQs in CT River Whole Smallmouth Bass

No piscivorous fish coplanar PCB TEQs in whole smallmouth bass approached either eco-risk screening level, however, a geographic gradient of lower levels was observed in the "upper" Reaches 6 and 7 (Figure 61). See the next section for parametric statistical analysis of the CT River piscivorous fish coplanar PCB TEQ data.

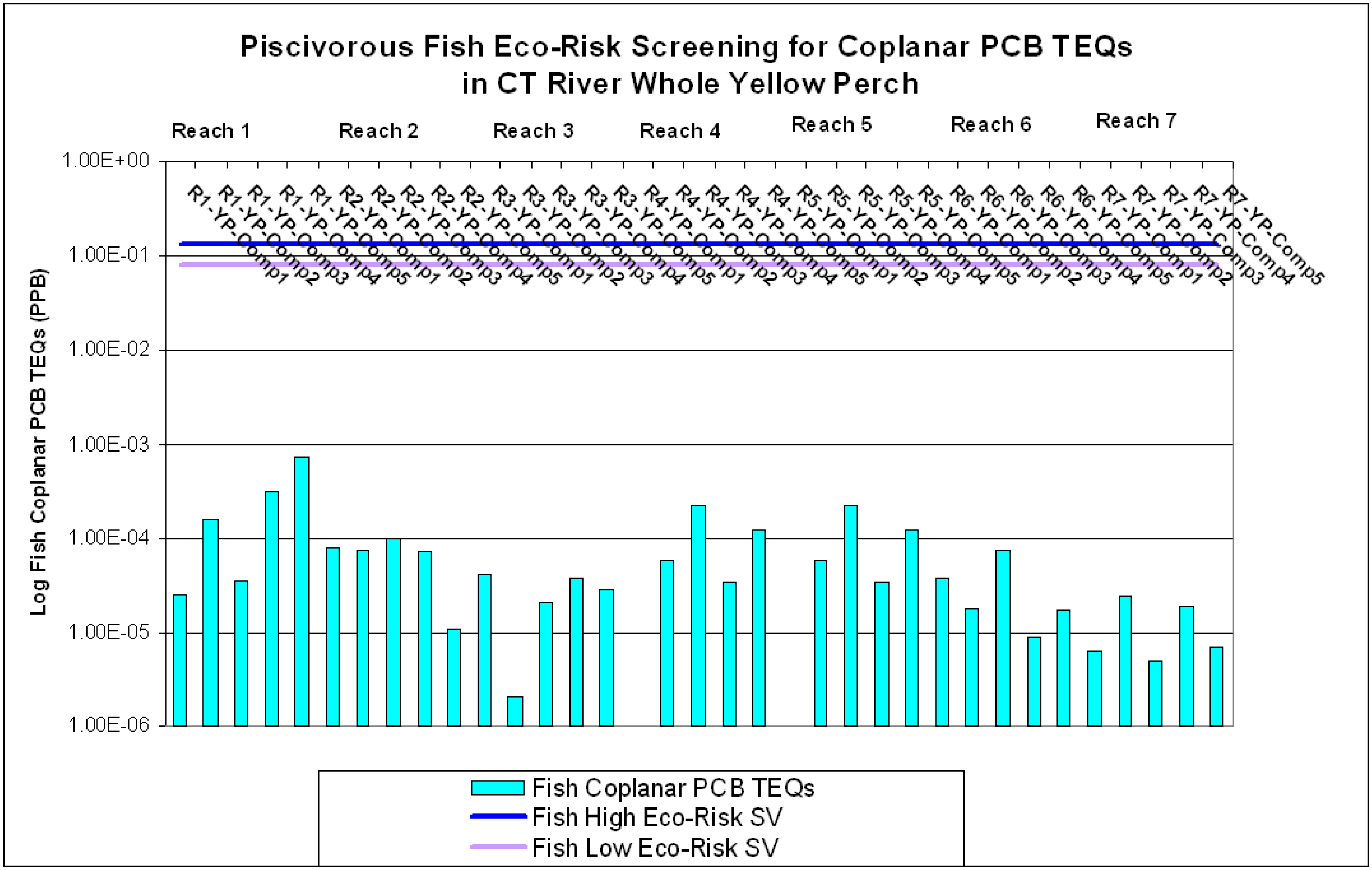

Figure 62. Piscivorous Fish Eco-Risk Screening for Coplanar PCB TEQs in CT River Whole Yellow Perch

No piscivorous fish coplanar PCB TEQs in whole yellow perch approached either eco-risk screening level (Figure 62). One sample each in Reach 4 and Reach 5 had no detectable levels of fish-eating fish coplanar PCB TEQ toxicity.

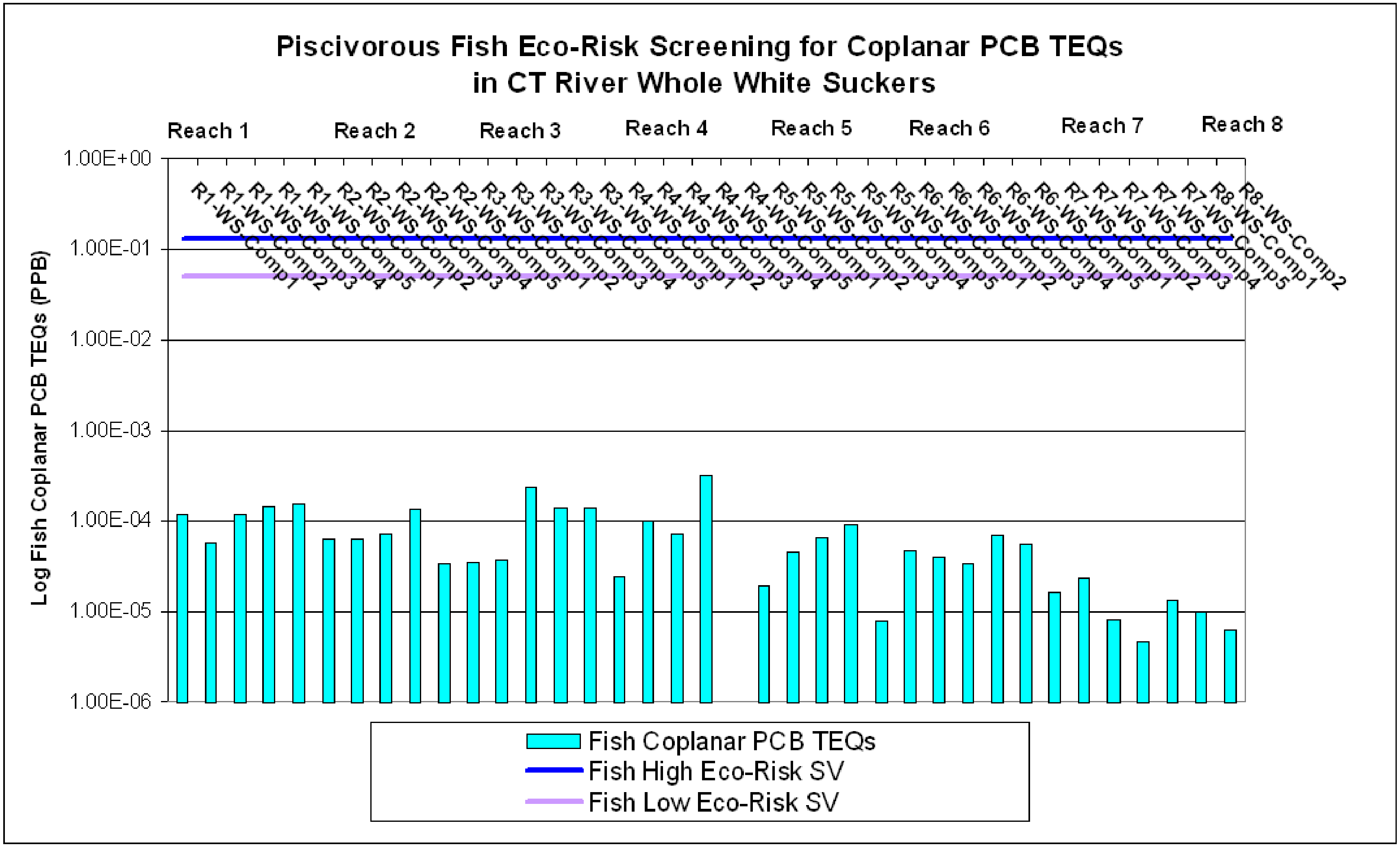

Figure 63. Piscivorous Fish Eco-Risk Screening for Coplanar PCB TEQs in CT River Whole White Suckers

No piscivorous fish coplanar PCB TEQs in whole white suckers approached either eco-risk screening level (Figure 63). One sample in Reach 4 had no detectable level of fish-eating fish coplanar PCB TEQ toxicity. An apparent geographic gradient of lower levels was observed in Reach 7 (Figure 61). See the next section for parametric statistical comparison by Reach of CT River fish-eating fish coplanar PCB TEQ data.

3.6 Coplanar PCB TEQ Human Health and Eco-Risk Screening - Summary

Table 25 summarizes the percentage of Connecticut River fillet and whole fish samples from all Reaches above PCB TEQ human health and eco-risk screening values.

Table 25. Percentage of Fillet and Whole Fish Samples from all Reaches above PCB TEQ Human Health and Eco-Risk Screening Values

Species	Fillet or Whole Fish	% > Subsistence Fisher CSV	% > Recreational Fisher CSV	% > Mammal Low and High Eco-Risk SV		% > Bird Low and High Eco-Risk SV		% > Fish Low and High Eco-Risk SV	
		3.15E-05 ppb	2.56E-04 ppb	7.00E-04 ppb	7.00E-03 ppb	0.006 ppb	0.06 ppb	0.05 ppb	0.08 ppb
Smallmouth Bass	Fillets	100%	51.4%						
	Whole	100%	98%	77%	14%	31%	3%	0%	0%
Yellow Perch	Fillets	86.5%	29.4%						
	Whole	100%	80%	63%	3%	26%	0%	0%	0%
White Sucker	Fillets	100%	73%						
	Whole	100%	86%	73%	0%	35%	3%	0%	0%

Coplanar PCB TEQs in all whole Connecticut River fish pose a potential carcinogenic health risk to subsistence fishers. 98% of whole smallmouth bass, 80% of whole yellow perch and 86% of whole white suckers pose a potential carcinogenic health risk to recreational fishers.

Coplanar PCB TEQs in all smallmouth bass and white sucker fillets and 86.5% of yellow perch fillets pose a potential carcinogenic health risk to subsistence fishers. 51.4% of smallmouth bass fillets, 29.4% of yellow perch fillets and 73% of white sucker fillets pose a potential carcinogenic health risk to recreational fishers.

Coplanar PCB TEQs in 77% of smallmouth bass, 63% of yellow perch and 73% of white suckers exceeded the low mammalian eco-risk SV. 14% of SMB, 3% of YP and no WS exceeded the high mammalian eco-risk SV. 31% of SMB, 26% of YP and 35% of WS exceeded the piscivorous bird low eco-risk SV. Only 3% of SMB and WS and no YP exceeded the high fish-eating bird eco-risk SV. No fish-eating fish coplanar PCB TEQs in any species exceeded either the low or high eco-risk SV.

If dioxin TEQs were available for the remainder of the whole fish samples, likely a much greater eco-risk to mammals would have been calculated. In the absence of the actual dioxin data in whole fish this conclusion is qualified by the widely divergent correlations observed between coplanar PCB TEQs for humans/mammalians, piscivorous fish, and piscivorous birds in whole and filleted fish in all three species (Table 26).

Table 26. Parametric Correlation (Pearson r) between Human/Mammalian, Piscivorous Fish and Piscivorous Bird Total Coplanar PCB TEQs in Whole and Filleted Fish by Species (correlations in red are statistically significant below 0.05)

PCB TEQs	Species	Parametric Correlation (Pearson r)
Total Human/Mammalian PCB TEQs	SMB	0.29
Total Piscivorous Fish PCB TEQs	SMB	**0.45**
Total Piscivorous Bird PCB TEQs	SMB	0.32
Total Human/Mammalian PCB TEQs	YP	**0.93**
Total Piscivorous Fish PCB TEQs	YP	**0.94**
Total Piscivorous Bird PCB TEQs	YP	0.29
Total Human/Mammalian PCB TEQs	WS	**0.62**
Total Piscivorous Fish PCB TEQs	WS	**0.39**
Total Piscivorous Bird PCB TEQs	WS	0.13

3.7 Correlation of Whole Fish Composite Total Weight and Coplanar PCB TEQs

3.7.1 Smallmouth Bass

No statistically significant parametric (Pearson) correlation (p=0.40) was observed in whole smallmouth bass between their total weight and human/mammalian coplanar PCB TEQs. Other, non-parametric correlation coefficients (Spearman R p=0.82; Kendall tau p=0.70; Gamma p=0.70) also found no significant correlation between total weight of whole smallmouth bass and the sum of human/mammalian PCB TEQs.

No statistically significant Pearson correlation (p=0.38) was observed in whole smallmouth bass between their total weight and fish coplanar PCB TEQs.

No statistically significant Pearson correlation (p=0.65) was observed in whole smallmouth bass between their total weight and bird receptor coplanar PCB TEQs.

3.7.2 Yellow Perch

A nearly statistically significant negative Pearson correlation (p=0.07) was found between whole yellow perch total weight and human/mammalian receptor coplanar PCB TEQs. However, this correlation was “driven” by a single outlier value. Furthermore, other non-parametric correlation coefficients found no statistically significant relationship between the total weight of whole yellow perch and the sum of human/mammalian PCB TEQs (Spearman R p=0.42; Kendall tau p=0.50; Gamma p=0.50).

No statistically significant correlation was observed (p=0.10) between whole yellow perch total weight and fish receptor coplanar PCB TEQs. The extremely large value in the upper left hand corner of the graph clearly ‘drives’ much of the observed relationship.

The total weight of yellow perch fillets was significantly correlated with the sum of human/mammalian PCB TEQs (Spearman R p=0.02; Kendall tau p=0.02; Gamma p=0.02).

No statistically significant correlation was observed (p=0.55) between whole yellow perch total weight and bird receptor coplanar PCB TEQs.

3.7.3 White Suckers

No statistically significant Pearson correlation (p=0.80) was observed in whole white suckers between their total weight and human/mammalian PCB TEQs. Other non-parametric correlation coefficients (Spearman R p=0.92; Kendall tau p=0.85; Gamma p=0.85) also found no significant relationship between total weight of whole white suckers and the sum of human/mammalian receptor coplanar PCB TEQs.

No statistically significant Pearson correlation (p=0.63) was observed in whole white suckers between their total weight and fish receptor coplanar PCB TEQs.

No statistically significant Pearson correlation (p=0.96) was observed in whole white suckers between their total weight and bird receptor coplanar PCB TEQs.

3.8 Coplanar PCB TEQs - ANOVA by Species and Reach
3.8.1 Human/Mammalian Receptor Coplanar PCB TEQs

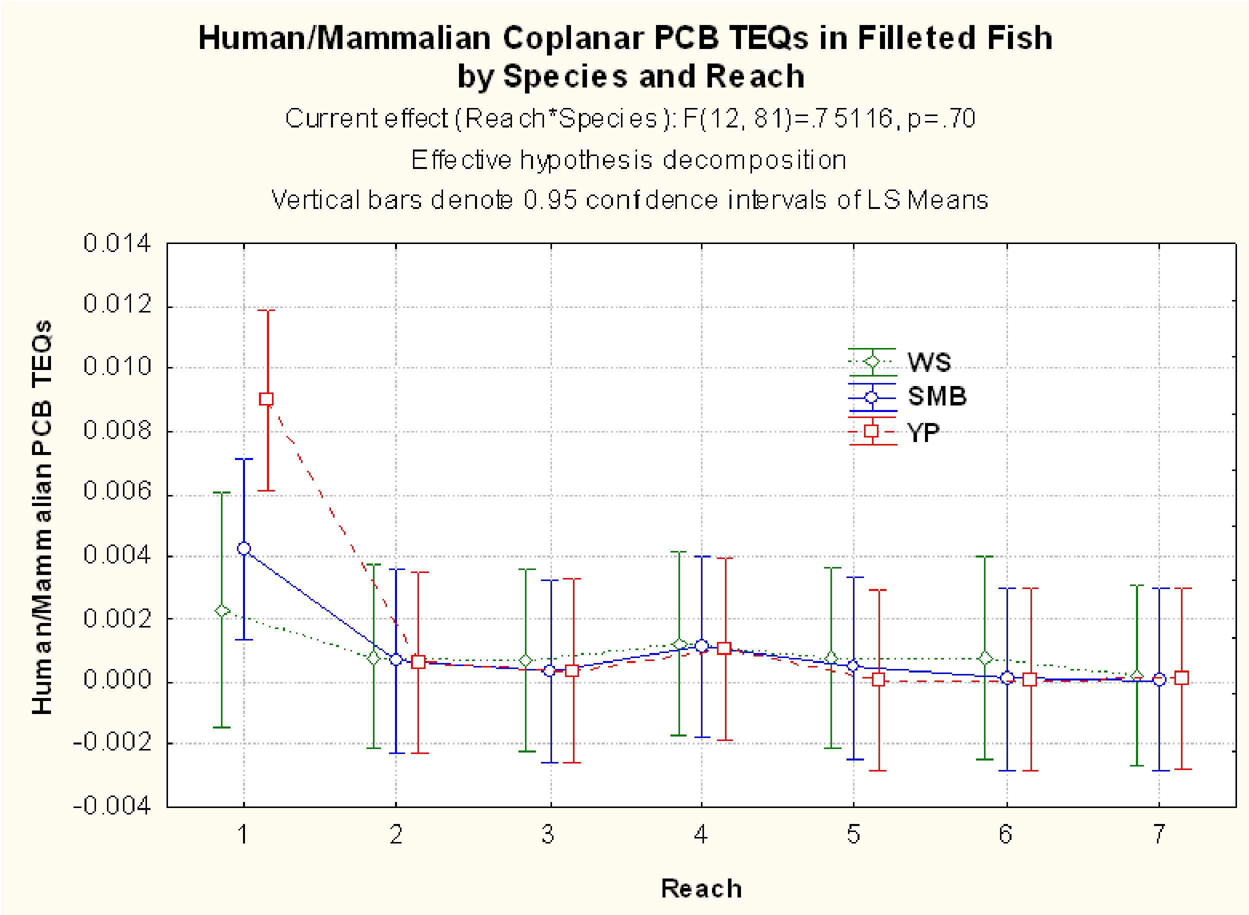

Figure 64. Factorial ANOVA of Human/Mammalian Coplanar PCB TEQs (ppb) in Filleted Fish by Species and Reach

A parametric statistical analysis (ANOVA) was performed on the PCB TEQ[41] data comparing species and Reaches to explore patterns in the data.

A factorial ANOVA found no significant effect (p=0.70) in human/mammalian coplanar PCB TEQs in filleted fish by species and Reach (Figure 64). Table 27 summarizes the pair-wise comparison of human/mammalian coplanar PCB TEQs in filleted fish by species and Reach using Fisher's LSD Test.

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[41]All TEQ units are in parts per billion (PPB) in the current study.

Table 27. Statistical Comparison of Human/Mammalian Coplanar PCB TEQs in Filleted Fish by Species and Reach (Fisher's LSD Post-Hoc Test of LS Means)

Least Square Means		0.002	0.004	0.009	0.00081	0.00067	0.00063	0.00071	0.00034	0.00037	0.00124	0.00112	0.00108	0.00077	0.00045	0.00004	0.00080	0.00009	0.00008	0.00019	0.00008	0.00013
	Spp.	WS	SMB	YP	WS	SMB	YP	WS	SMB	YP	WS	SMB	YP	WS	SMB	YP	WS	SMB	YP	WS	SMB	YP
Reach		1	1	1	2	2 2		3 3		3 4		4 4		5 5		5 6		6 6		7 7		7
1	WS		0.42	**0.01**	0.53	0.50	0.49	0.51	0.41	0.42	0.66	0.62	0.61	0.52	0.44	0.35	0.55	0.36	0.36	0.38	0.36	0.37
1	SMB			**0.02**	0.10	0.09	0.08	0.09	0.06	0.06	0.15	0.13	0.13	0.10	0.07	**0.04**	0.12	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
1	YP				**1.52E-04**	**1.20E-04**	**1.13E-04**	**1.28E-04**	**6.74E-05**	**7.17E-05**	**3.16E-04**	**2.57E-04**	**2.40E-04**	**1.42E-04**	**8.26E-05**	**4.02E-05**	**3.28E-04**	**4.37E-05**	**4.28E-05**	**5.19E-05**	**4.28E-05**	**4.70E-05**
2	WS					0.95	0.93	0.96	0.82	0.83	0.83	0.88	0.90	0.98	0.86	0.71	1.00	0.73	0.73	0.76	0.73	0.74
2	SMB						0.98	0.99	0.87	0.88	0.78	0.83	0.84	0.96	0.92	0.76	0.95	0.78	0.78	0.82	0.78	0.80
2	YP							0.97	0.89	0.90	0.77	0.81	0.83	0.95	0.93	0.78	0.94	0.79	0.79	0.83	0.79	0.81
3	WS								0.86	0.87	0.80	0.84	0.86	0.98	0.90	0.75	0.97	0.77	0.76	0.80	0.76	0.78
3	SMB									0.99	0.66	0.71	0.72	0.83	0.96	0.89	0.83	0.91	0.90	0.94	0.90	0.92
3	YP										0.67	0.72	0.73	0.85	0.97	0.87	0.85	0.89	0.89	0.93	0.89	0.91
4	WS											0.95	0.94	0.82	0.70	0.56	0.84	0.58	0.57	0.61	0.57	0.59
4	SMB												0.98	0.87	0.75	0.60	0.88	0.62	0.62	0.65	0.62	0.63
4	YP													0.88	0.76	0.62	0.90	0.63	0.63	0.67	0.63	0.65
5	WS														0.88	0.73	0.99	0.74	0.74	0.78	0.74	0.76
5	SMB															0.84	0.88	0.86	0.86	0.90	0.86	0.88
5	YP																0.73	0.98	0.99	0.94	0.99	0.97
6	WS																	0.75	0.74	0.78	0.74	0.76
6	SMB																		1.00	0.96	1.00	0.98
6	YP																			0.96	1.00	0.98
7	WS																				0.96	0.98
7	SMB																					0.98

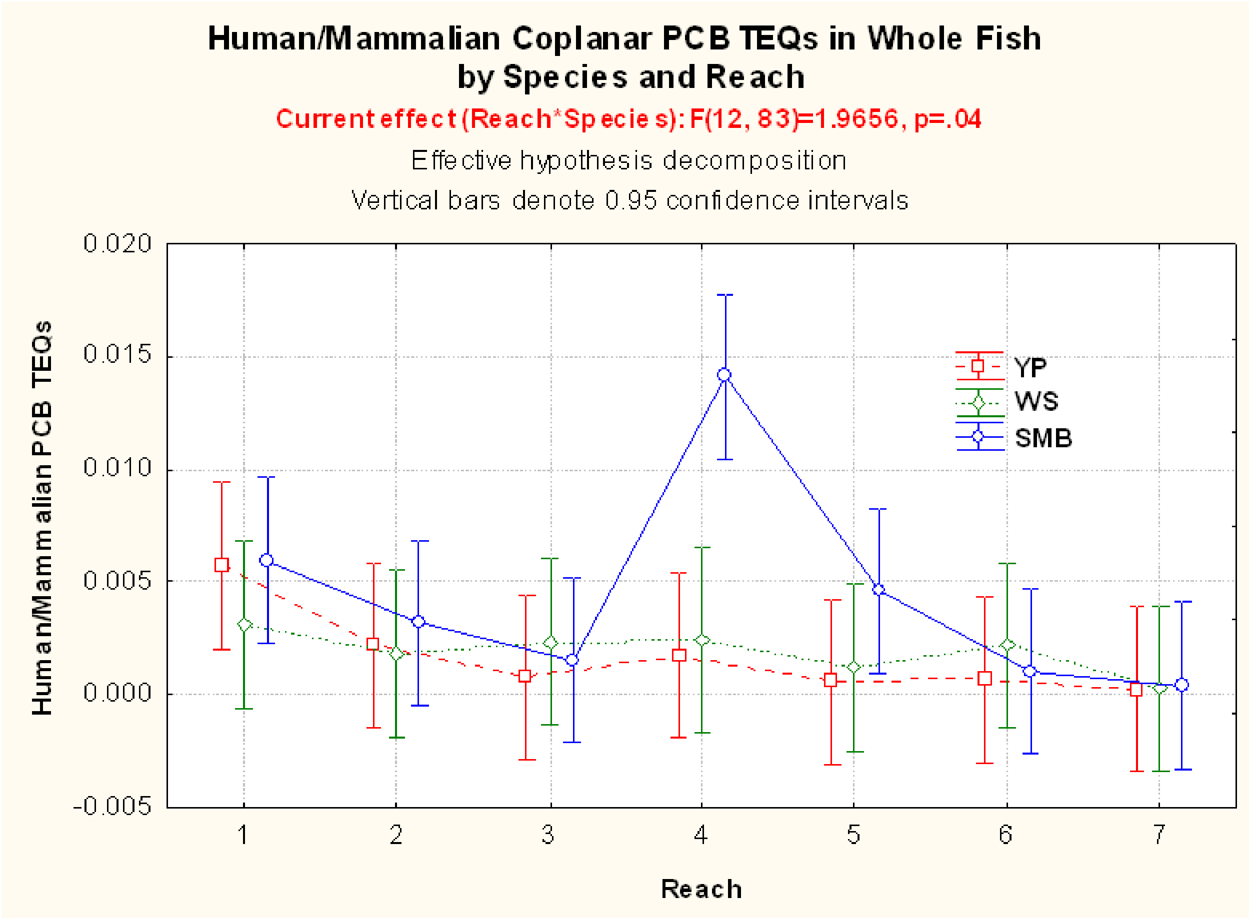

Figure 65. Factorial ANOVA of Human/Mammalian Coplanar PCB TEQs (ppb) in Whole Fish by Species and Reach

A factorial ANOVA found a marginally significant effect (p=0.04) in human/mammalian coplanar PCB TEQs in whole fish by species and Reach (Figure 65). Table 28 summarizes the pair-wise comparison of human/mammalian coplanar PCB TEQs in whole fish by species and Reach using Fisher's LSD Test.

Table 28. Statistical Comparison of Human/Mammalian Coplanar PCB TEQs in Whole Fish by Species and Reach (Fisher's LSD Post-Hoc Test of LS Means)

Least Square Means		0.0058	0.0031	0.0060	0.0022	0.0019	0.0032	0.0008	0.0024	0.0016	0.0018	0.0024	0.0141	0.0006	0.0012	0.0046	0.0007	0.0022	0.0011	0.0003	0.0003	0.0004
	Spp.	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**
Reach		**1 1**	**1**	**2**	**2**	**2**	**3**	**3**	**3**	**4**	**4**		**4**	**5**	**5**	**5**	**6**	**6 6**	**7**	**7**		**7**
1	**YP**		0.32	0.93	0.18	0.14	0.33	0.06	0.20	0.11	0.13	0.24	**1.97E-03**	**0.05**	0.09	0.66	0.06	0.18	0.08	**0.04**	**0.04**	**0.05**
1	**WS**			0.28	0.72	0.62	0.98	0.37	0.77	0.55	0.60	0.80	**6.81E-05**	0.33	0.47	0.58	0.35	0.72	0.43	0.27	0.28	0.30
1	**SMB**				0.15	0.12	0.30	**0.05**	0.17	0.10	0.11	0.21	**2.53E-03**	**0.04**	0.07	0.60	**0.05**	0.15	0.06	**0.03**	**0.03**	**0.04**
2	**YP**					0.90	0.70	0.59	0.95	0.81	0.87	0.93	**1.77E-05**	0.54	0.71	0.36	0.57	1.00	0.66	0.46	0.47	0.50
2	**WS**						0.60	0.69	0.84	0.91	0.98	0.83	**1.07E-05**	0.63	0.81	0.30	0.66	0.89	0.76	0.55	0.55	0.59
2	**SMB**							0.36	0.75	0.53	0.58	0.78	**7.52E-05**	0.32	0.45	0.60	0.34	0.70	0.41	0.26	0.27	0.29
3	**YP**								0.55	0.77	0.71	0.56	**2.19E-06**	0.94	0.87	0.15	0.97	0.59	0.92	0.84	0.84	0.89
3	**WS**									0.76	0.82	0.98	**2.27E-05**	0.50	0.66	0.39	0.53	0.95	0.62	0.42	0.43	0.46
3	**SMB**										0.94	0.75	**6.99E-06**	0.71	0.90	0.25	0.74	0.81	0.85	0.62	0.62	0.67
4	**YP**											0.81	**9.58E-06**	0.65	0.83	0.28	0.68	0.87	0.78	0.56	0.57	0.61
4	**WS**												**6.46E-05**	0.51	0.66	0.44	0.53	0.93	0.62	0.44	0.44	0.47
4	**SMB**													**1.62E-06**	**4.21E-06**	**4.80E-04**	**1.89E-06**	**1.80E-05**	**3.24E-06**	**9.58E-07**	**9.79E-07**	**1.24E-06**
5	**YP**														0.81	0.13	0.97	0.54	0.86	0.90	0.90	0.95
5	**WS**															0.20	0.84	0.71	0.95	0.71	0.72	0.76
5	**SMB**																0.14	0.36	0.18	0.10	0.10	0.11
6	**YP**																	0.57	0.89	0.87	0.87	0.92
6	**WS**																		0.66	0.46	0.46	0.50
6	**SMB**																			0.76	0.77	0.81
7	**YP**																				1.00	0.95
7	**WS**																					0.95

3.8.1.1 Smallmouth Bass

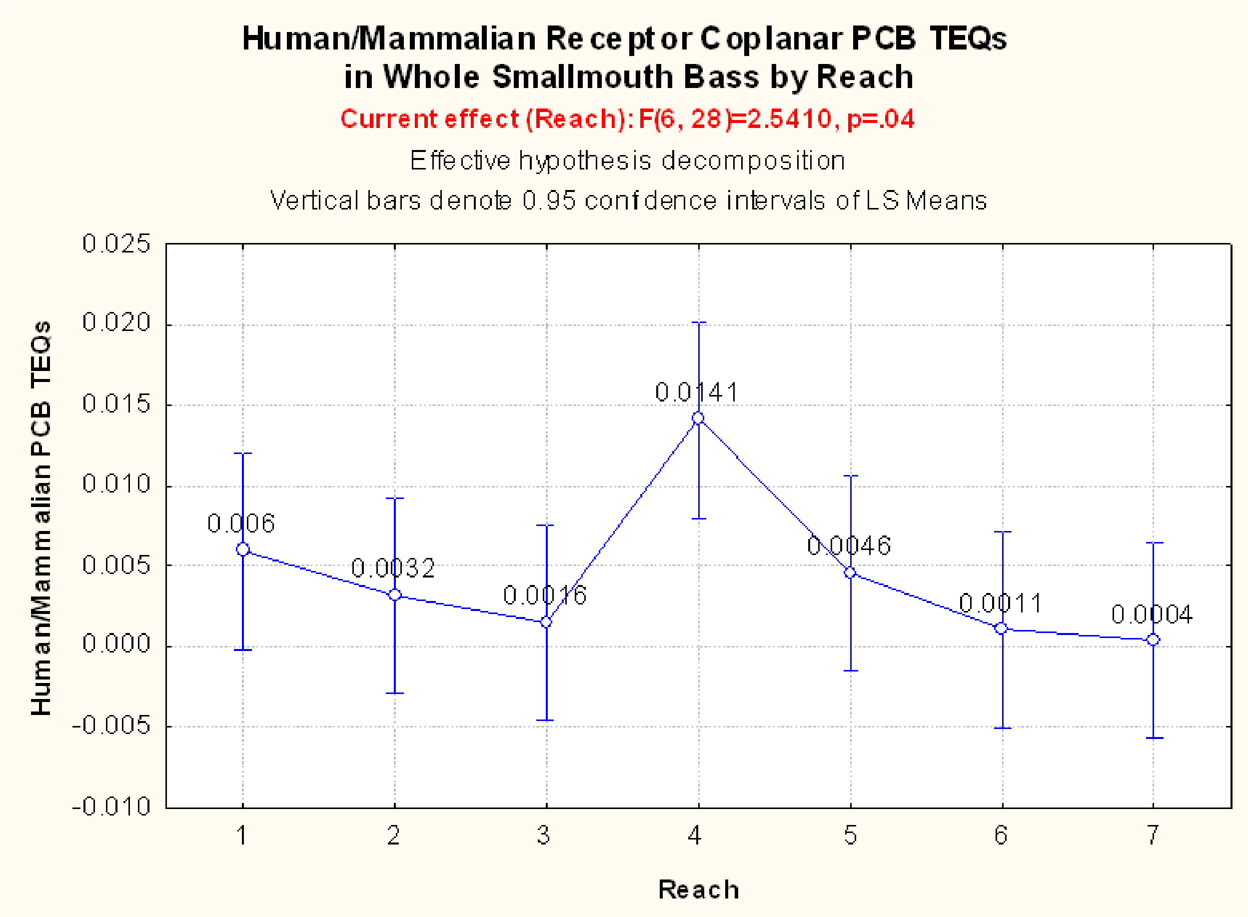

Figure 66. ANOVA of Human/Mammalian Receptor Coplanar PCB TEQs (ppb) in Whole Smallmouth Bass by Reach

A one-way ANOVA found a marginally significant effect for Reach (p=0.04) in human/mammalian coplanar PCB TEQs in whole smallmouth bass (Figure 66). Table 29 summarizes the pair-wise comparison of human/mammalian coplanar PCB TEQs in whole smallmouth bass by Reach using Fisher's LSD Test. The only significant differences were found between Reach 4 and all other Reaches, except Reach 1, which was marginally non-significant. It is unclear if this difference reflects a true geographic pattern or is a sampling artifact.

Table 29. Statistical Comparison of Human/Mammalian Coplanar PCB TEQs in Whole Smallmouth Bass by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	0.0060	0.0032	0.0016	0.0141	0.0046	0.0011	0.0004
Reach	**1 2**	**3**	**4**	**5**	**6**	**7**	
1		0.52	0.30	0.06	0.75	0.25	0.20
2			0.70	**0.01**	0.74	0.61	0.51
3				**0.01**	0.47	0.90	0.79
4					**0.03**	**4.13E-03**	**2.83E-03**
5						0.40	0.33
6							0.88

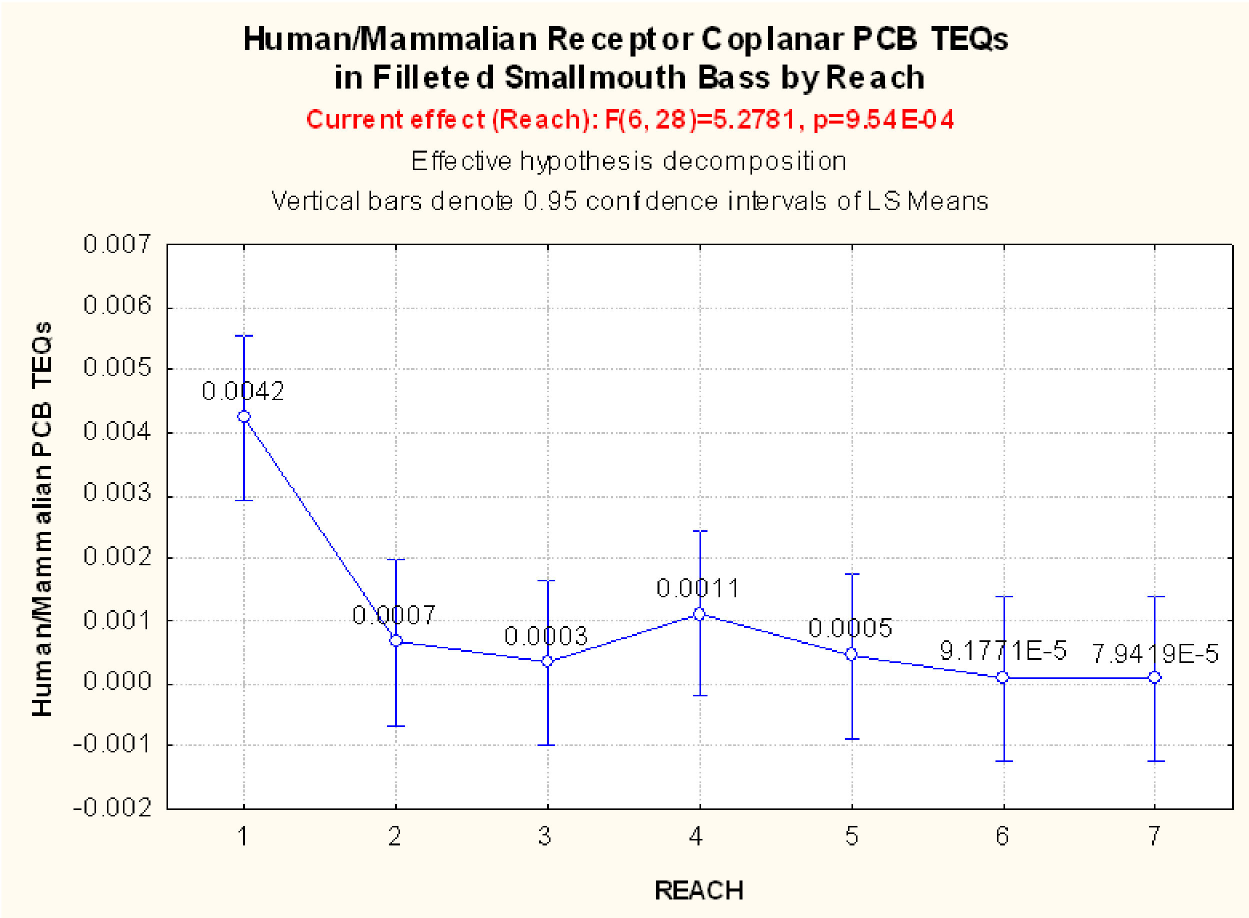

Figure 67. ANOVA of Human/Mammalian Receptor Coplanar PCB TEQs (ppb) in Filleted Smallmouth Bass by Reach

A one-way ANOVA found a highly significant effect for Reach (p=9.54E-04) in human/mammalian coplanar PCB TEQs in filleted smallmouth bass (Figure 67). Table 30 summarizes the pair-wise comparison of human/mammalian coplanar PCB TEQs in whole smallmouth bass by Reach using Fisher's LSD Test. Reach 1 was significantly different than all other Reaches.

Table 30. Statistical Comparison of Human/Mammalian Coplanar PCB TEQs in Filleted Smallmouth Bass by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	0.00425	0.00067	0.00034	0.00112	0.00045	0.00009	0.00008
Reach	**1 2**	**3**	**4**	**5**	**6**	**7**	
1		5.00E-04	1.85E-04	1.83E-03	2.62E-04	8.93E-05	8.60E-05
2			0.72	0.63	0.81	0.53	0.52
3				0.40	0.90	0.79	0.78
4					0.47	0.27	0.26
5						0.69	0.68
6							0.99

3.8.1.2 Yellow Perch

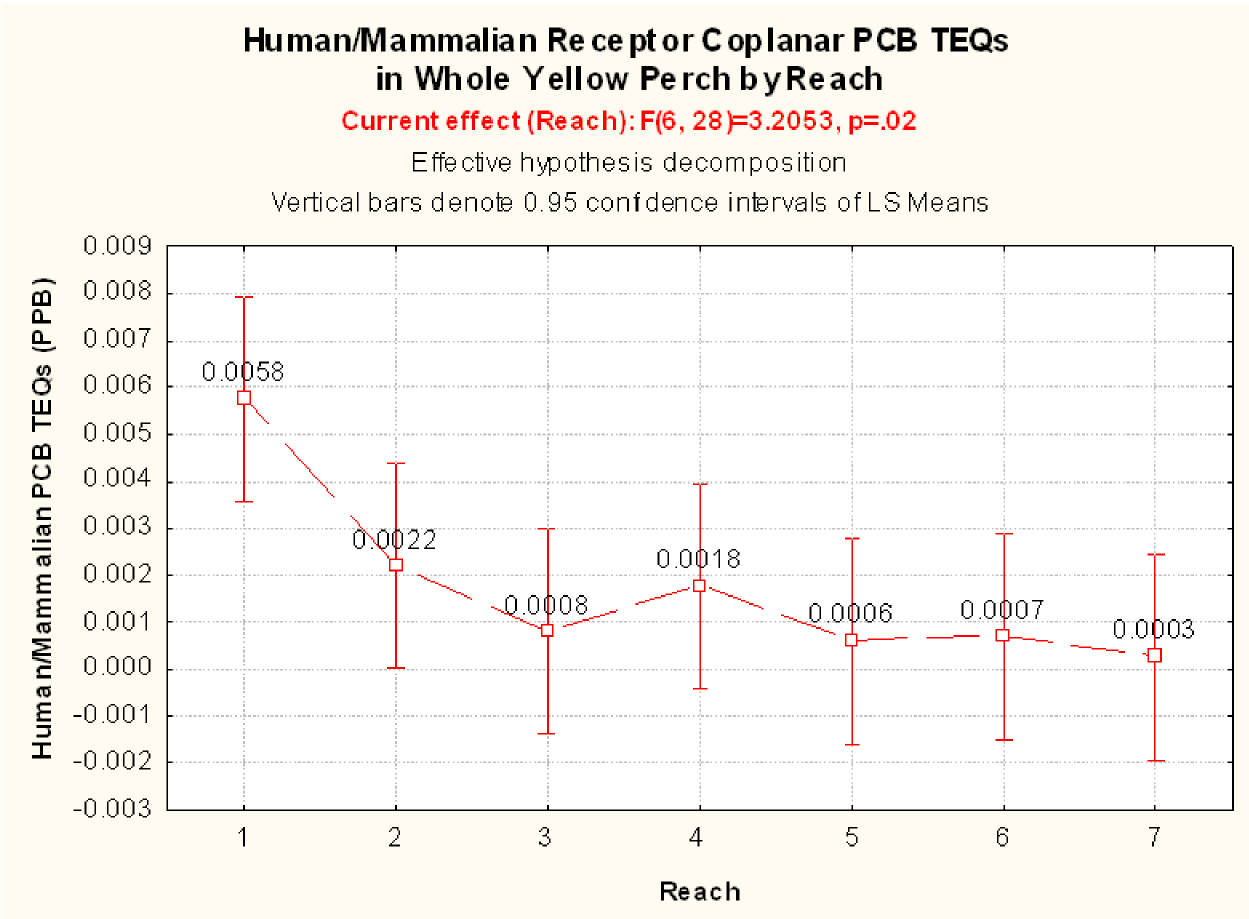

Figure 68. Human/Mammalian Receptor Coplanar PCB TEQs (ppb) in Whole Yellow Perch by Reach

A one-way ANOVA found a significant effect for Reach (p=0.02) in human/mammalian coplanar PCB TEQs in whole yellow perch (Figure 68). Table 31 summarizes the pair-wise comparison of human/mammalian coplanar PCB TEQs in whole yellow perch by Reach using Fisher's LSD Test. Reach 1 was significantly higher than all other Reaches.

Table 31. Statistical Comparison of Human/Mammalian Coplanar PCB TEQs in Whole Yellow Perch by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	**0.0058**	**0.0022**	**0.0008**	**0.0018**	**0.0006**	**0.0007**	**0.0003**
Reach	**1 2**	**3**	**4**	**5**	**6**	**7**	
1		**0.03**	**2.68E-03**	**0.01**	**1.92E-03**	**2.27E-03**	**1.07E-03**
2			0.36	0.78	0.30	0.33	0.21
3				0.52	0.90	0.95	0.72
4					0.44	0.48	0.32
5						0.95	0.82
6							0.77

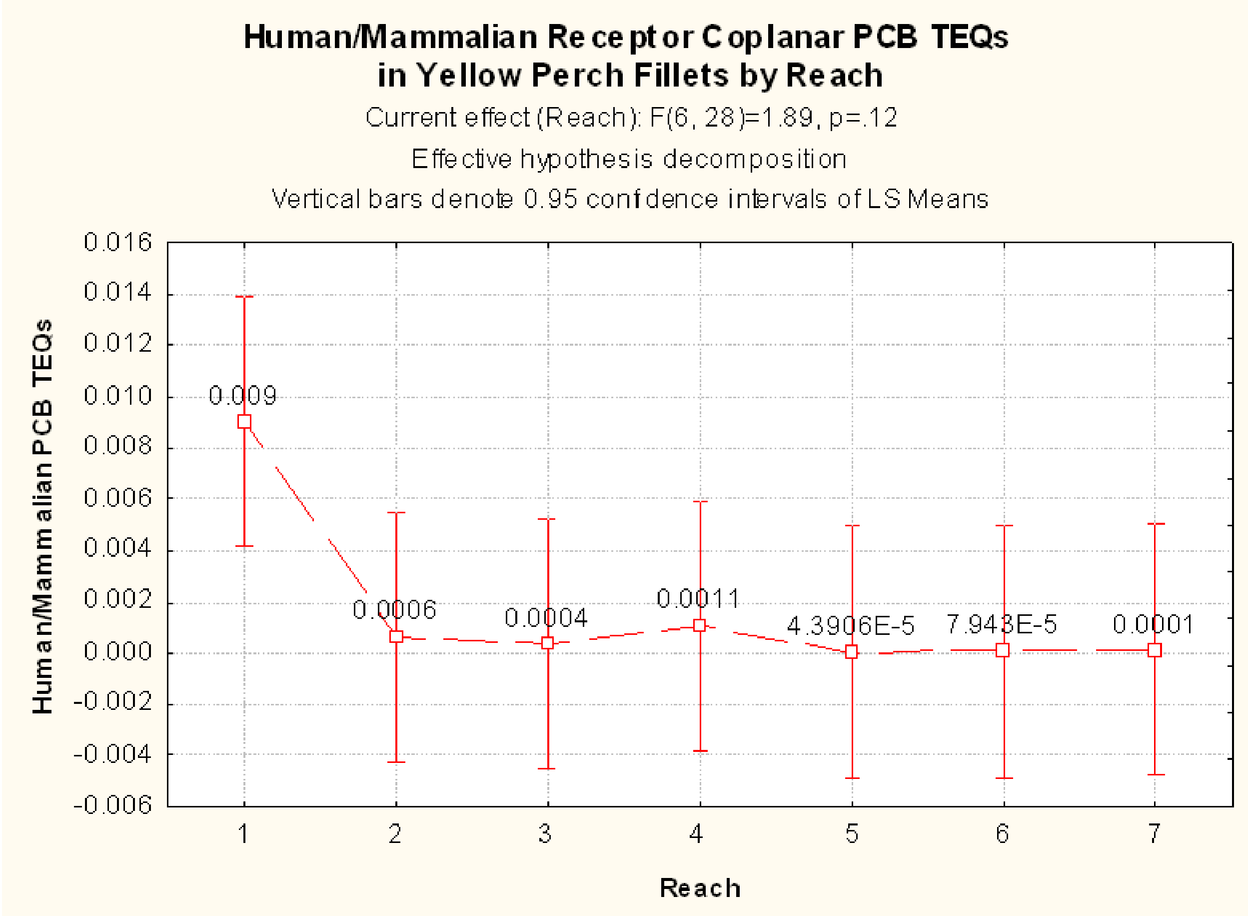

Figure 69. ANOVA of Human/Mammalian Receptor Coplanar PCB TEQs (ppb) in Yellow Perch Fillets by Reach

A one-way ANOVA found no significant effect for Reach (p=0.12) in human/mammalian coplanar PCB TEQs in yellow perch fillets (Figure 67). Table 32 summarizes the pair-wise comparison of human/mammalian coplanar PCB TEQs in whole yellow perch by Reach using Fisher's LSD Test. Reach 1 was significantly higher than all other Reaches.

Table 32. Statistical Comparison of Human/Mammalian Coplanar PCB TEQs in Filleted Yellow Perch by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	**0.00901**	**0.00063**	**0.00037**	**0.00108**	**0.00004**	**0.00008**	**0.00013**
Reach	**1 2**	**3**	**4**	**5**	**6**	**7**	
1		**0.02**	**0.02**	**0.03**	**0.01**	**0.01**	**0.01**
2			0.94	0.90	0.86	0.87	0.88
3				0.84	0.92	0.93	0.94
4					0.76	0.77	0.78
5						0.99	0.98
6							0.99

3.8.1.3 White Suckers

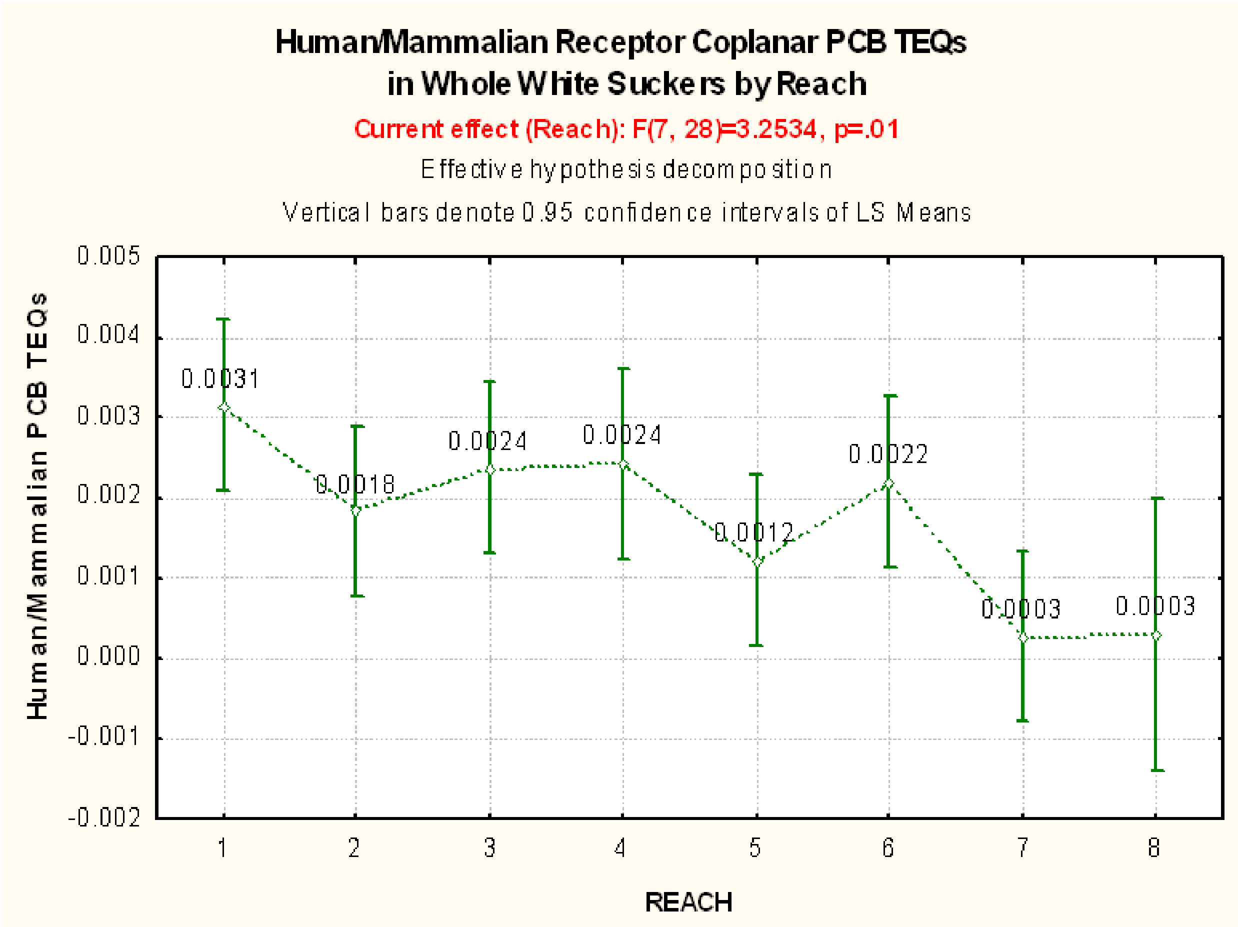

Figure 70. ANOVA of Human/Mammalian Coplanar PCB TEQs (ppb) in Whole White Suckers by Reach

A one-way ANOVA found a significant effect for Reach (p=0.01) in human/mammalian coplanar PCB TEQs in whole white suckers (Figure 70). Table 33 summarizes the pair-wise comparison of human/mammalian coplanar PCB TEQs in whole white suckers by Reach using Fisher's LSD Test. Reach 1 was significantly different than Reaches 5, 7 and 8. Reach 7 was significantly different than all Reaches, except 5. Reach 8 was significantly different than Reaches 1, 3, and 4.

Table 33. Statistical Comparison of Human/Mammalian Coplanar PCB TEQs in Whole White Suckers by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	0.0031	0.0019	0.0024	0.0024	0.0012	0.0022	0.0003	0.0003
REACH	**1 2**	**3**	**4**	**5**	**6**	**7**	**8**	
1		0.09	0.30	0.37	**0.01**	0.21	**5.50E-04**	**0.01**
2			0.49	0.46	0.40	0.63	**0.04**	0.12
3				0.93	0.13	0.83	**0.01**	**0.04**
4					0.13	0.77	**0.01**	**0.04**
5						0.19	0.21	0.35
6							**0.01**	0.06
7								0.97

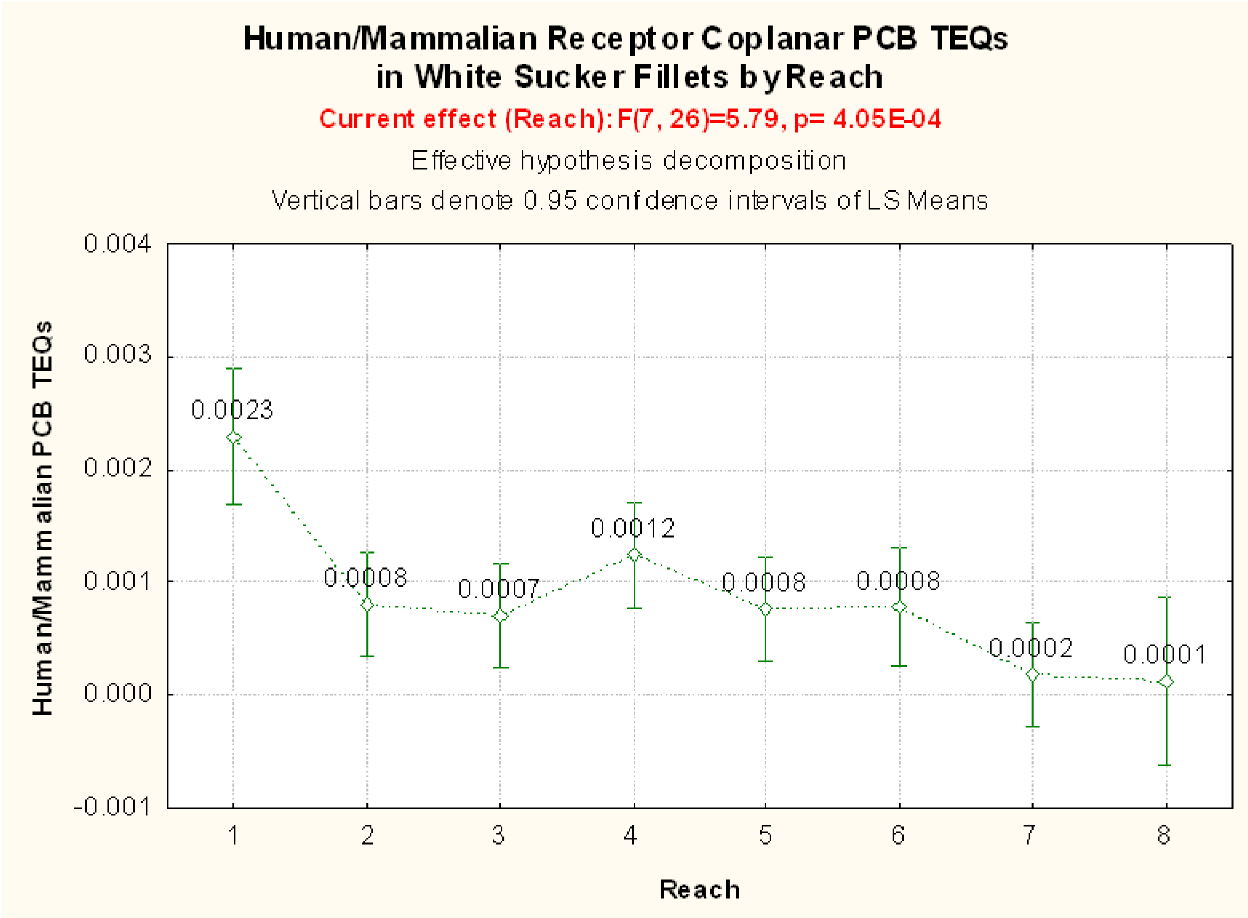

Figure 71. ANOVA of Human/Mammalian Receptor Coplanar PCB TEQs (ppb) in White Sucker Fillets by Reach

A one-way ANOVA found a significant effect for Reach (p=4.05E-04) in human/mammalian coplanar PCB TEQs in filleted white suckers (Figure 71). Table 34 summarizes the pair-wise comparison of human/mammalian coplanar PCB TEQs in white sucker fillets by Reach using Fisher's LSD Test. Reach 1 was significantly different than all other Reaches. Reaches 7 and 8 were significantly different than Reach 4.

Table 34. Statistical Comparison of Human/Mammalian Coplanar PCB TEQs in Filleted White Suckers by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	0.00230	0.00081	0.00071	0.00124	0.00077	0.00080	0.00019	0.00012
REACH	1 2	3	4	5	6	7	8	
1		4.54E-04	2.20E-04	0.01	3.42E-04	6.60E-04	5.60E-06	7.67E-05
2			0.75	0.19	0.90	0.97	0.06	0.12
3				0.11	0.85	0.79	0.12	0.18
4					0.15	0.20	2.91E-03	0.01
5						0.94	0.08	0.14
6							0.09	0.14
7								0.88

3.8.1.4 Human/Mammalian Coplanar PCB TEQs - ANOVA Summary

A factorial ANOVA found a marginally significant effect (p=0.04) in human/mammalian coplanar PCB TEQs in whole fish by species and Reach. However, a factorial ANOVA found no significant effect (p=0.70) in human/mammalian coplanar PCB TEQs in filleted fish by species and Reach.

A one-way ANOVA found a marginally significant effect for Reach (p=0.04) in human/mammalian coplanar PCB TEQs in whole smallmouth bass. Whole smallmouth bass had significantly higher levels of PCB TEQs in Reach 4 than all Reaches, except Reach 1.

A one-way ANOVA found a highly significant effect for Reach (p=9.54E-04) in human/mammalian coplanar PCB TEQs in filleted smallmouth bass. However, in filleted smallmouth bass only Reach 1 had significantly higher levels of PCB TEQs than other Reaches.

A one-way ANOVA found a significant effect for Reach (p=0.02) in human/mammalian coplanar PCB TEQs in whole yellow perch. Whole yellow perch had significantly higher levels of PCB TEQs in Reach 1 than all other Reaches.

A one-way ANOVA found no significant effect for Reach (p=0.12) in human/mammalian coplanar PCB TEQs in yellow perch fillets. Filleted yellow perch had a similar pattern to whole yellow perch.

A one-way ANOVA found a significant effect for Reach (p=0.01) in human/mammalian coplanar PCB TEQs in whole white suckers. Whole white suckers had significantly lower levels of PCB TEQs in Reaches 7 and 8 than in many other Reaches. Reach 1 was also significantly higher than Reach 5.

A one-way ANOVA found a significant effect for Reach (p=4.05E-04) in human/mammalian coplanar PCB TEQs in filleted white suckers. Filleted white suckers had significantly higher levels of PCB TEQs in Reach 1. Also Reach 4 was significantly higher than Reaches 7 and 8.

It is possible higher levels in Reach 1 reflect the increasing effects of urbanization in the lower watershed. This could be explored in subsequent analyses. However, any such analysis must also attempt to account for the interspecific differences in contaminant loads by Reach.

3.8.2 Piscivorous (Fish-eating) Bird Coplanar PCB TEQs

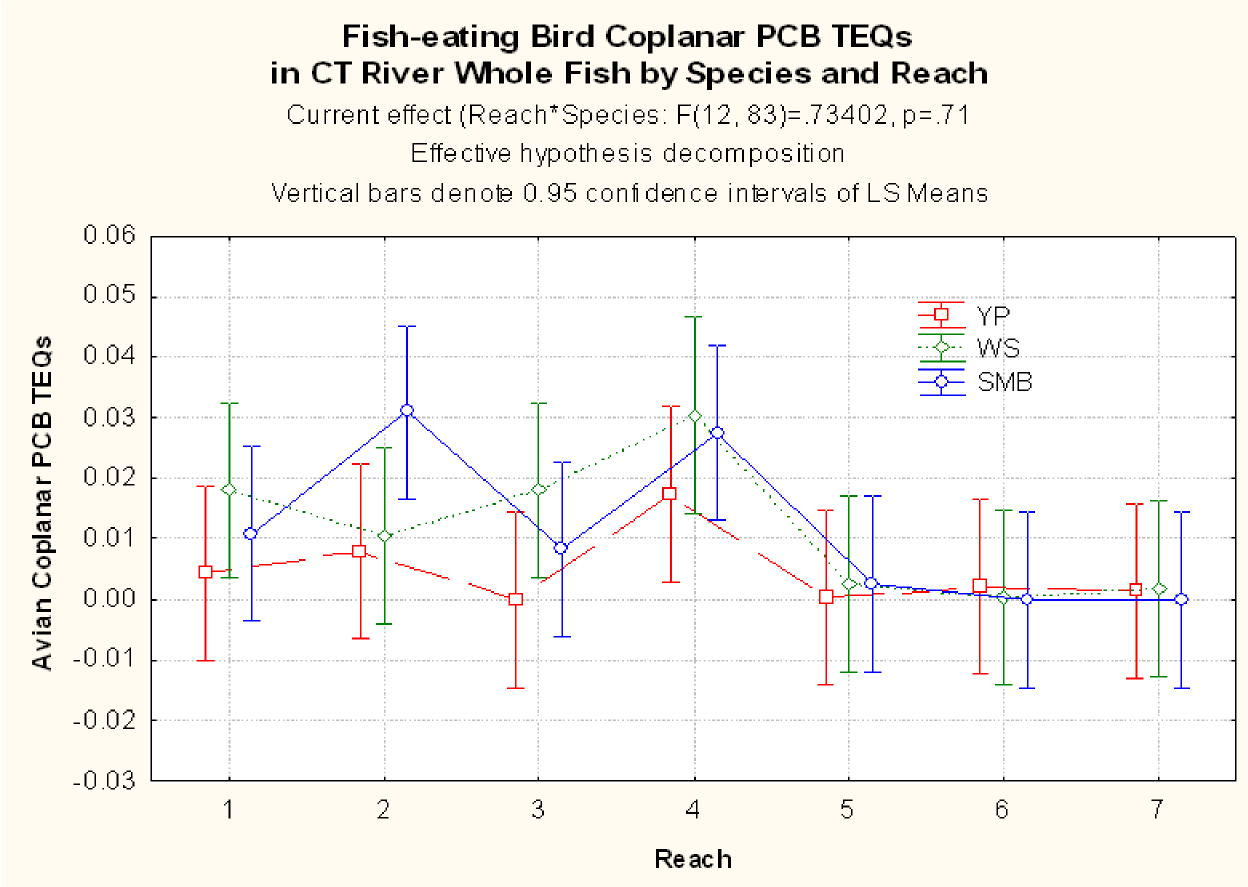

Figure 72. Factorial ANOVA of Fish-eating Bird Coplanar PCB TEQs (ppb) in CT River Whole Fish by Specie and Reach

A factorial ANOVA found no significant effect (p=0.71) in fish-eating bird coplanar PCB TEQs in whole fish by species and Reach (Figure 72). Table 35 summarizes the pair-wise comparison of human/mammalian coplanar PCB TEQs in whole fish by species and Reach using Fisher's LSD Test. While significant differences were observed[42], no clear geographic patterns were found among Reaches.

[42] We might expect from statistical principles, with an alpha level of 0.05, that a matrix of 231 elements would yield approximately 11 or 12 statistically significant differences simply by chance. In the bird PCB TEQ matrix we found 39 significant differences among Reaches, many more than would be expected simply by chance.

Table 35. Statistical Comparison of Fish-eating Bird Coplanar PCB TEQs by Species and Reach
(Fisher's LSD Post-Hoc Test of LS Means)

Least Square Means		0.004	0.018	0.011	0.008	0.010	0.031	0.0001	0.018	0.008	0.017	0.030	0.028	0.0002	0.003	0.002	0.002	0.0004	0.0001	0.001	0.002	0.00006
	Spp.	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**	**YP**	**WS**	**SMB**
Reach		**1 1**	**1**	**2**	**2**	**2**		**3**	**3 3**	**4**	**4**	**4**		**5**	**5 5**	**6**		**6**	**6**	**7 7**		**7**
1	**YP**		0.18	0.53	0.73	0.56	**0.01**	0.68	0.18	0.69	0.21	**0.02**	**0.03**	0.69	0.86	0.85	0.83	0.70	0.68	0.78	0.81	0.68
1	**WS**			0.48	0.32	0.45	0.22	0.08	0.99	0.35	0.93	0.26	0.36	0.08	0.13	0.13	0.12	0.09	0.08	0.11	0.12	0.08
1	**SMB**				0.77	0.96	**0.05**	0.30	0.47	0.82	0.53	0.08	0.11	0.30	0.42	0.42	0.40	0.31	0.30	0.36	0.38	0.30
2	**YP**					0.81	**0.03**	0.45	0.31	0.95	0.36	**0.04**	0.06	0.46	0.61	0.60	0.58	0.47	0.46	0.54	0.56	0.45
2	**WS**						**0.05**	0.32	0.45	0.85	0.50	0.07	0.10	0.33	0.45	0.44	0.43	0.34	0.32	0.39	0.41	0.32
2	**SMB**							**3.54E-03**	0.22	**0.03**	0.19	0.96	0.74	**3.68E-03**	**0.01**	**0.01**	**0.01**	**3.90E-03**	**3.58E-03**	**0.01**	**0.01**	**3.49E-03**
3	**YP**								0.08	0.42	0.10	**0.01**	**0.01**	0.99	0.81	0.82	0.84	0.97	1.00	0.89	0.87	1.00
3	**WS**									0.34	0.93	0.27	0.37	0.08	0.13	0.13	0.12	0.09	0.08	0.11	0.11	0.08
3	**SMB**										0.39	**0.05**	0.07	0.42	0.57	0.56	0.54	0.44	0.42	0.50	0.52	0.41
4	**YP**											0.23	0.32	0.10	0.16	0.15	0.14	0.10	0.10	0.13	0.14	0.10
4	**WS**												0.79	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
4	**SMB**													**0.01**	**0.02**	**0.02**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
5	**YP**														0.82	0.83	0.85	0.98	0.99	0.90	0.88	0.99
5	**WS**															0.99	0.97	0.84	0.81	0.92	0.94	0.81
5	**SMB**																0.98	0.85	0.82	0.93	0.95	0.82
6	**YP**																	0.87	0.84	0.95	0.98	0.84
6	**WS**																		0.98	0.92	0.89	0.97
6	**SMB**																			0.90	0.87	0.99
7	**YP**																				0.97	0.89
7	**WS**																					0.86

3.8.2.1 Smallmouth Bass

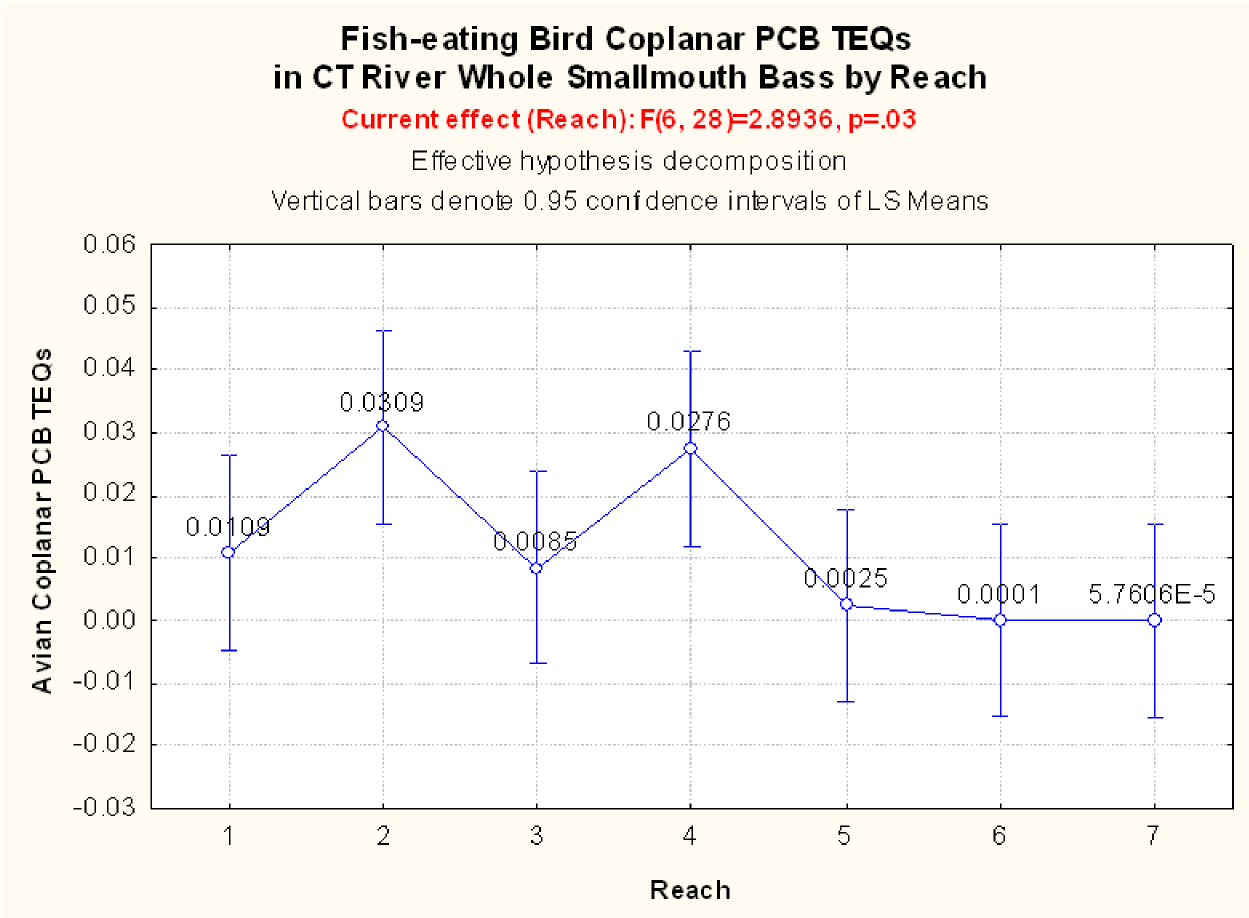

Figure 73. ANOVA of Fish-eating Bird Coplanar PCB TEQs (ppb) in CT River Whole Smallmouth Bass by Reach

A one-way ANOVA found a significant effect for Reach (p=0.03) in fish-eating bird coplanar PCB TEQs in whole smallmouth bass (Figure 73). Table 36 summarizes the pair-wise comparison of fish-eating coplanar PCB TEQs in whole smallmouth bass by Reach using Fisher's LSD Test. Reaches 2 and 4 were significantly higher than Reaches 5, 6 and 7. Reach 2 was also significantly higher than Reach 3.

Table 36. Statistical Comparison of Fish-eating Bird Coplanar PCB TEQs in Whole Smallmouth Bass by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	**0.01085**	**0.03092**	**0.00848**	**0.02756**	**0.00245**	**0.00014**	**0.00006**
Reach	**1 2**	**3**	**4**	**5**	**6**	**7**	
1		0.07	0.83	0.13	0.44	0.32	0.32
2			**0.04**	0.75	**0.01**	**0.01**	**0.01**
3				0.08	0.58	0.44	0.44
4					**0.03**	**0.02**	**0.02**
5						0.83	0.82
6							0.99

3.8.2.2 Yellow Perch

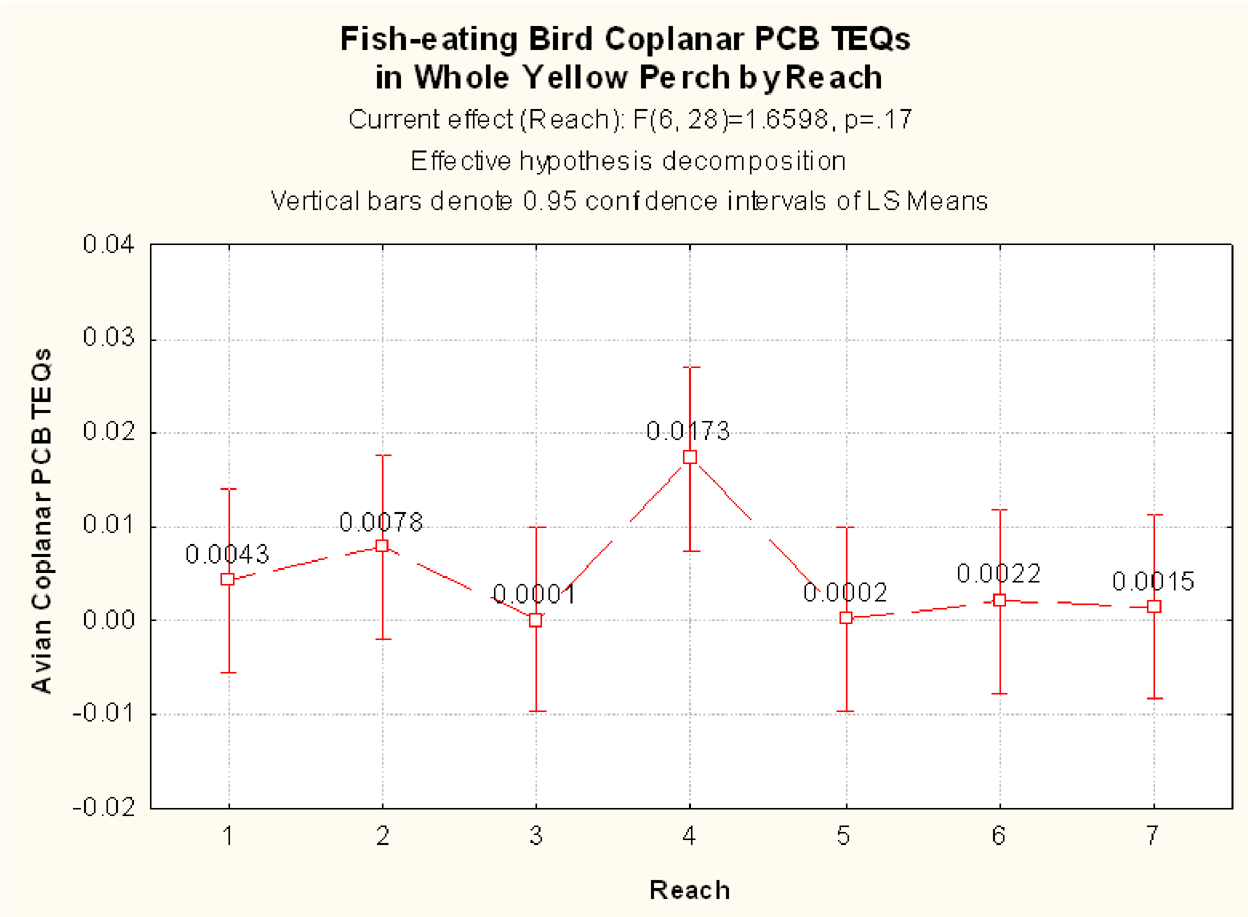

Figure 74. ANOVA of Fish-eating Bird Coplanar PCB TEQs (ppb) in CT River Whole Yellow Perch by Reach

A one-way ANOVA found no significant effect for Reach (p=0.17) in fish-eating coplanar PCB TEQs in whole yellow perch (Figure 74). Table 37 summarizes the pair-wise comparison of fish-eating coplanar PCB TEQs in whole smallmouth bass by Reach using Fisher's LSD Test. Reach 4 was significantly higher than Reaches 3, 5, 6, and 7.

Table 37. Statistical Comparison of Fish-eating Bird Coplanar PCB TEQs in Whole Yellow Perch by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	0.0043	0.0079	0.0001	0.0173	0.0002	0.0022	0.0015
Reach	**1 2**	**3**	**4**	**5**	**6**	**7**	
1		0.61	0.53	0.07	0.55	0.75	0.67
2			0.26	0.17	0.27	0.41	0.35
3				**0.02**	0.98	0.76	0.84
4					**0.02**	**0.03**	**0.03**
5						0.78	0.85
6							0.92

3.8.2.3 White Suckers

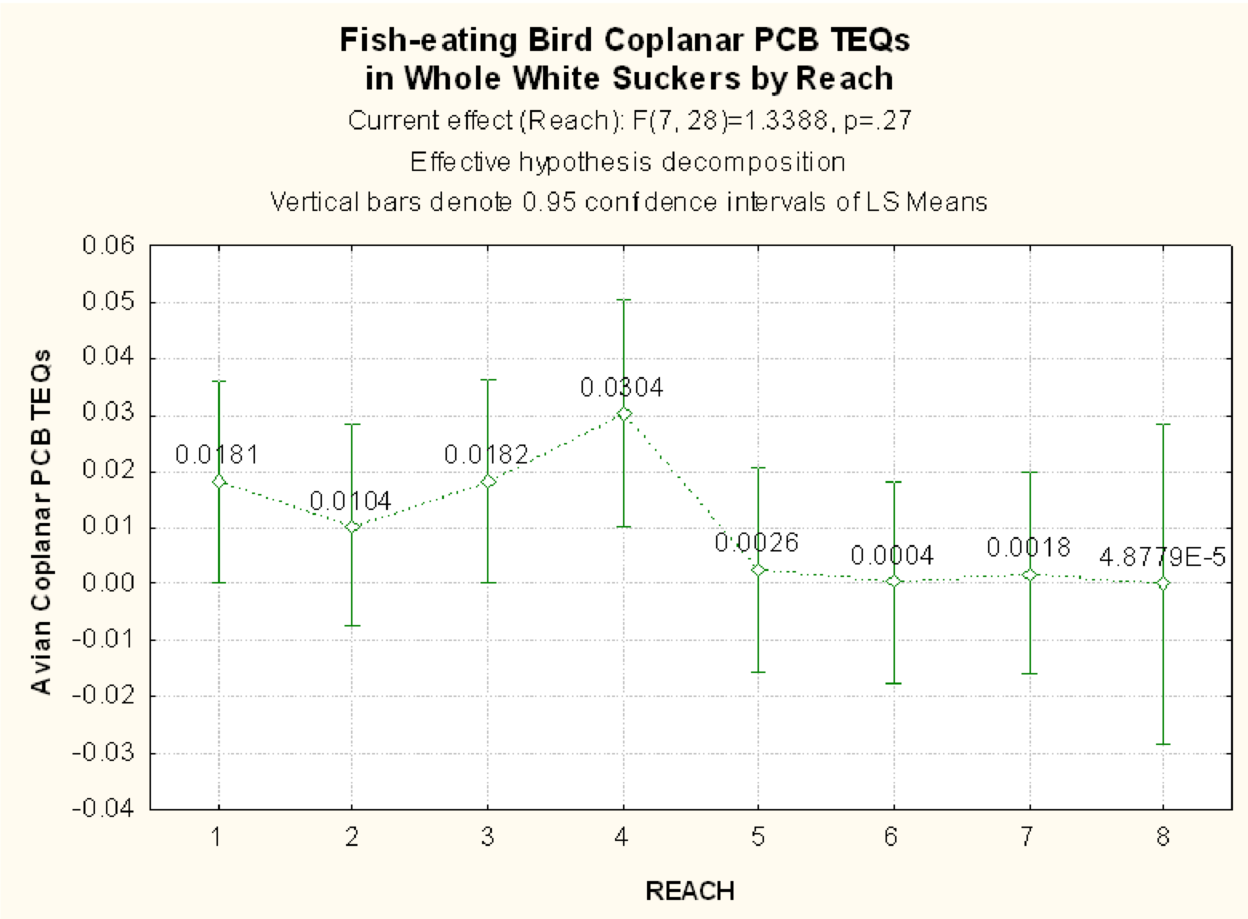

Figure 75. ANOVA of Fish-eating Bird Coplanar PCB TEQs (ppb) in CT River Whole White Suckers by Reach

A one-way ANOVA found no significant effect for Reach (p=0.27) in fish-eating coplanar PCB TEQs in whole white suckers (Figure 75). Table 38 summarizes the pair-wise comparison of fish-eating coplanar PCB TEQs in whole white suckers by Reach using Fisher's LSD Test. Reach 4 was significantly higher than Reaches 5, 6, and 7.

Table 38. Statistical Comparison of Fish-eating Bird Coplanar PCB TEQs in Whole Yellow Perch by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	**0.01814**	**0.01036**	**0.01823**	**0.03041**	**0.00256**	**0.00044**	**0.00184**	**0.00005**
REACH	**1 2**	**3**	**4**	**5**	**6**	**7**	**8**	
1		0.53	0.99	0.36	0.22	0.16	0.20	0.28
2			0.53	0.14	0.53	0.43	0.50	0.53
3				0.36	0.22	0.16	0.20	0.28
4					**0.04**	**0.03**	**0.04**	0.08
5						0.87	0.95	0.88
6							0.91	0.98
7								0.91

3.8.2.4 Piscivorous (Fish-eating) Bird Coplanar PCB TEQs - ANOVA Summary

A factorial ANOVA found no significant effect (p=0.71) in fish-eating bird coplanar PCB TEQs in whole fish by species and Reach. While significant differences were observed among Reaches and species, no clear geographic patterns were found.

A one-way ANOVA found a significant effect for Reach (p=0.03) in fish-eating bird coplanar PCB TEQs in whole smallmouth bass. In whole smallmouth bass fish-eating bird coplanar PCB TEQs in Reaches 2 and 4 were significantly higher than Reaches 5, 6 and 7. Reach 2 was also significantly higher than Reach 3.

A one-way ANOVA found no significant effect for Reach (p=0.17) in fish-eating coplanar PCB TEQs in whole smallmouth bass. In whole yellow perch fish-eating bird coplanar PCB TEQs in Reach 4 were significantly higher than Reaches 3, 5, 6, and 7.

A one-way ANOVA found no significant effect for Reach (p=0.27) in fish-eating coplanar PCB TEQs in whole white suckers. However, fish-eating bird coplanar PCB TEQs in Reach 4 in whole white suckers were significantly higher than Reaches 5, 6, and 7.

3.8.3 Piscivorous (Fish-eating) Fish Coplanar PCB TEQs

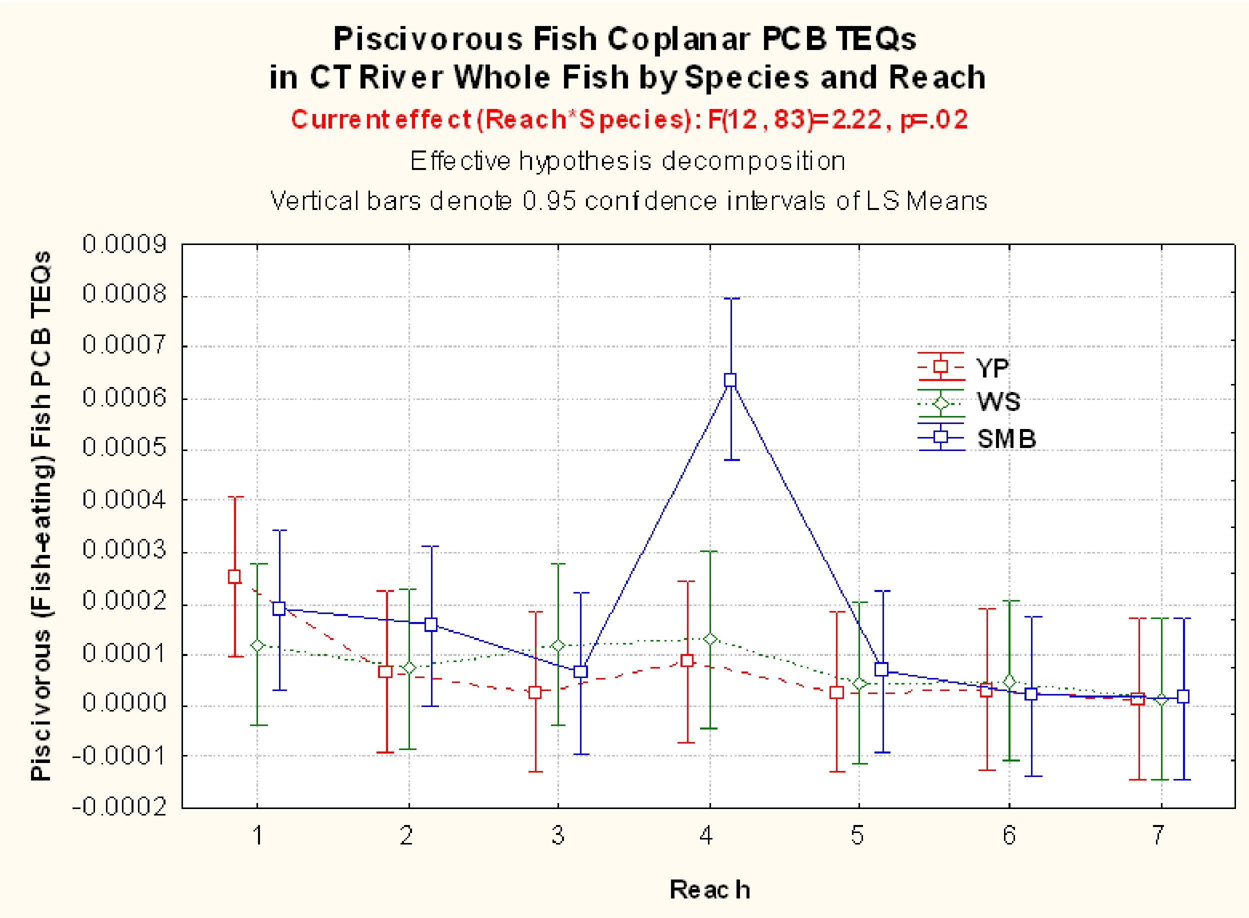

Figure 76. Factorial ANOVA of Piscivorous (Fish-eating) Fish Coplanar PCB TEQs (ppb) in CT River Whole Fish by Species and Reach

A factorial ANOVA found a significant effect (p=0.02) in piscivorous (fish-eating) fish coplanar PCB TEQs in whole fish by species and Reach (Figure 76). Table 39 summarizes the pair-wise comparison of human/mammalian coplanar PCB TEQs in whole fish by species and Reach using Fisher's LSD Test. Reach 4 in smallmouth bass was significantly higher than all other combinations of Reaches and species. Significant differences were also found between Reach 1 in yellow perch with Reaches 3, 5, 6, and 7 in yellow perch. Reach 1 in yellow perch was also significantly different than smallmouth bass in Reaches 6 and 7 and white suckers in Reach 7.

Table 39. Statistical Comparison of Piscivorous (Fish-eating) Fish Coplanar PCB TEQs by Species and Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means		0.0003	0.0001	0.0002	0.00007	0.00007	0.00016	0.00003	0.00012	0.00007	0.00009	0.00013	0.00064	0.00003	0.00004	0.00007	0.00003	0.00005	0.00002	0.00001	0.00001	0.00002
Reach		1	1	1	2 2		2 3		3 3		4 4		4 5		5 5		6 6		6 7		7 7	
	SPP.	YP	WS	SMB	YP	WS	SMB	YP	WS	SMB	YP	WS	SMB	YP	WS	SMB	YP	WS	SMB	YP	WS	SMB
1	YP		0.24	0.56	0.10	0.11	0.39	**0.05**	0.23	0.10	0.14	0.30	**9.08E-04**	**0.05**	0.07	0.10	**0.05**	0.07	**0.04**	**0.03**	**0.03**	**0.04**
1	WS			0.55	0.64	0.68	0.74	0.40	0.99	0.63	0.77	0.93	**1.32E-05**	0.41	0.50	0.64	0.43	0.53	0.38	0.34	0.34	0.36
1	SMB				0.29	0.31	0.79	0.15	0.54	0.28	0.37	0.63	**1.23E-04**	0.16	0.21	0.29	0.17	0.22	0.14	0.12	0.12	0.13
2	YP					0.96	0.42	0.71	0.65	0.99	0.86	0.60	**2.06E-06**	0.72	0.84	0.99	0.75	0.87	0.68	0.63	0.63	0.65
2	WS						0.46	0.67	0.69	0.94	0.90	0.64	**2.58E-06**	0.68	0.80	0.96	0.71	0.83	0.64	0.59	0.59	0.61
2	SMB							0.24	0.73	0.41	0.53	0.82	**4.61E-05**	0.25	0.32	0.43	0.26	0.34	0.23	0.20	0.20	0.21
3	YP								0.41	0.73	0.59	0.38	**4.57E-07**	0.99	0.86	0.71	0.96	0.83	0.96	0.90	0.91	0.93
3	WS									0.63	0.78	0.93	**1.26E-05**	0.41	0.51	0.65	0.44	0.54	0.38	0.34	0.35	0.36
3	SMB										0.85	0.59	**1.93E-06**	0.73	0.86	0.98	0.76	0.89	0.69	0.64	0.64	0.66
4	YP											0.72	**4.17E-06**	0.59	0.71	0.87	0.62	0.74	0.56	0.51	0.51	0.53
4	WS												**4.89E-05**	0.39	0.48	0.60	0.41	0.50	0.36	0.32	0.33	0.34
4	SMB													**4.75E-07**	**9.23E-07**	**2.12E-06**	**5.57E-07**	**1.08E-06**	**3.76E-07**	**2.76E-07**	**2.84E-07**	**3.17E-07**
5	YP														0.87	0.71	0.97	0.84	0.96	0.90	0.90	0.92
5	WS															0.84	0.90	0.97	0.83	0.77	0.78	0.80
5	SMB																0.74	0.87	0.67	0.62	0.63	0.64
6	YP																	0.87	0.92	0.87	0.87	0.89
6	WS																		0.80	0.74	0.75	0.77
6	SMB																			0.94	0.95	0.97
7	YP																				0.99	0.97
7	WS																					0.98

3.8.3.1 Smallmouth Bass

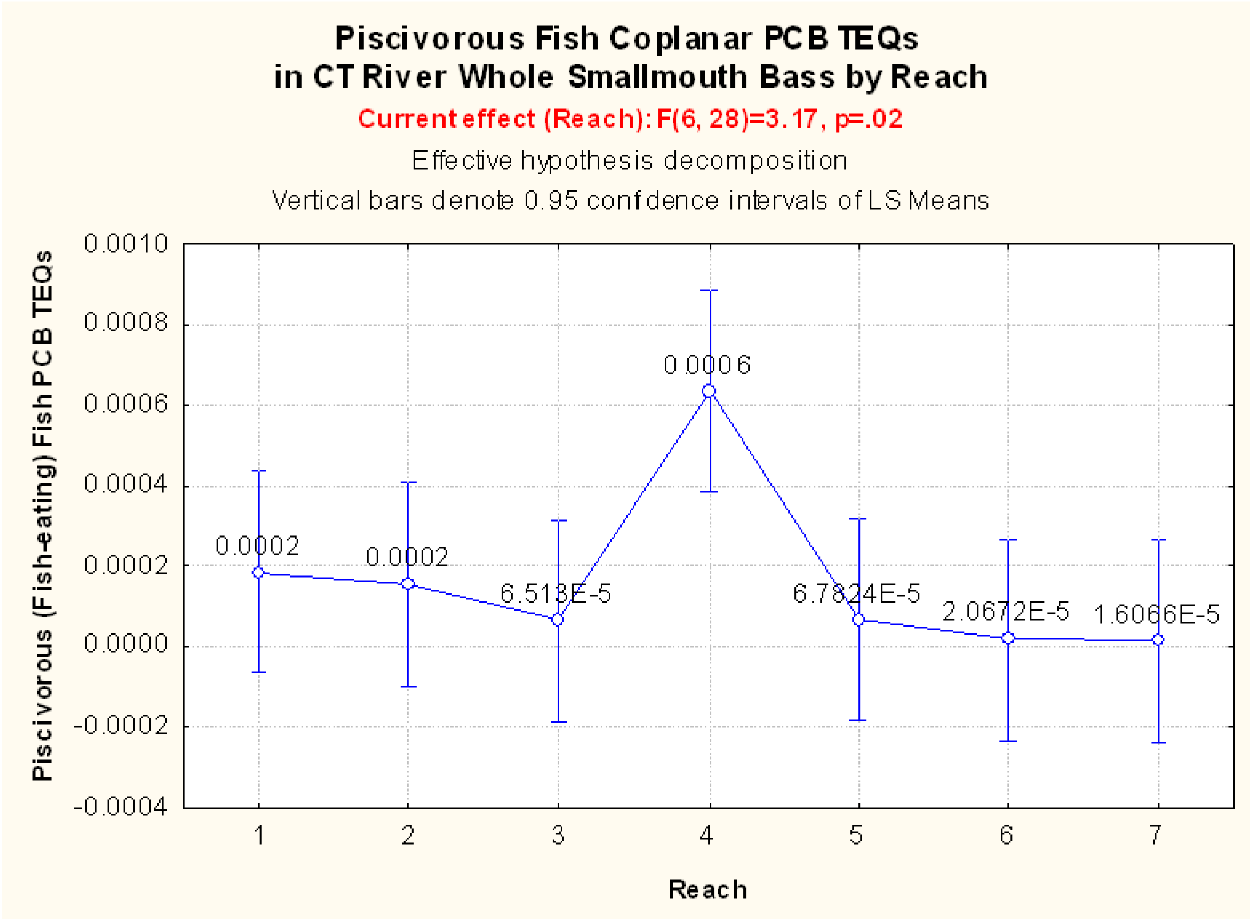

Figure 77. ANOVA of Piscivorous (Fish-eating) Fish Coplanar PCB TEQs (ppb) in CT River Whole Smallmouth Bass by Reach

A one-way ANOVA found a significant effect for Reach (p=0.02) in piscivorous (fish-eating) fish coplanar PCB TEQs in whole smallmouth bass (Figure 77). Table 40 summarizes the pair-wise comparison of fish-eating coplanar PCB TEQs in whole smallmouth bass by Reach using Fisher's LSD Test. Reach 4 was significantly higher than all other Reaches.

Table 40. Statistical Comparison of Fish-eating Bird Coplanar PCB TEQs in Whole Smallmouth Bass by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	**0.00019**	**0.00016**	**0.00007**	**0.00064**	**0.00007**	**0.00002**	**0.00002**
Reach	**1 2**	**3**	**4**	**5**	**6**	**7**	
1		0.86	0.49	**0.01**	0.50	0.35	0.33
2			0.60	**0.01**	0.61	0.44	0.42
3				**2.66E-03**	0.99	0.80	0.78
4					**2.76E-03**	**1.37E-03**	**1.28E-03**
5						0.79	0.77
6							0.98

3.8.3.2 Yellow Perch

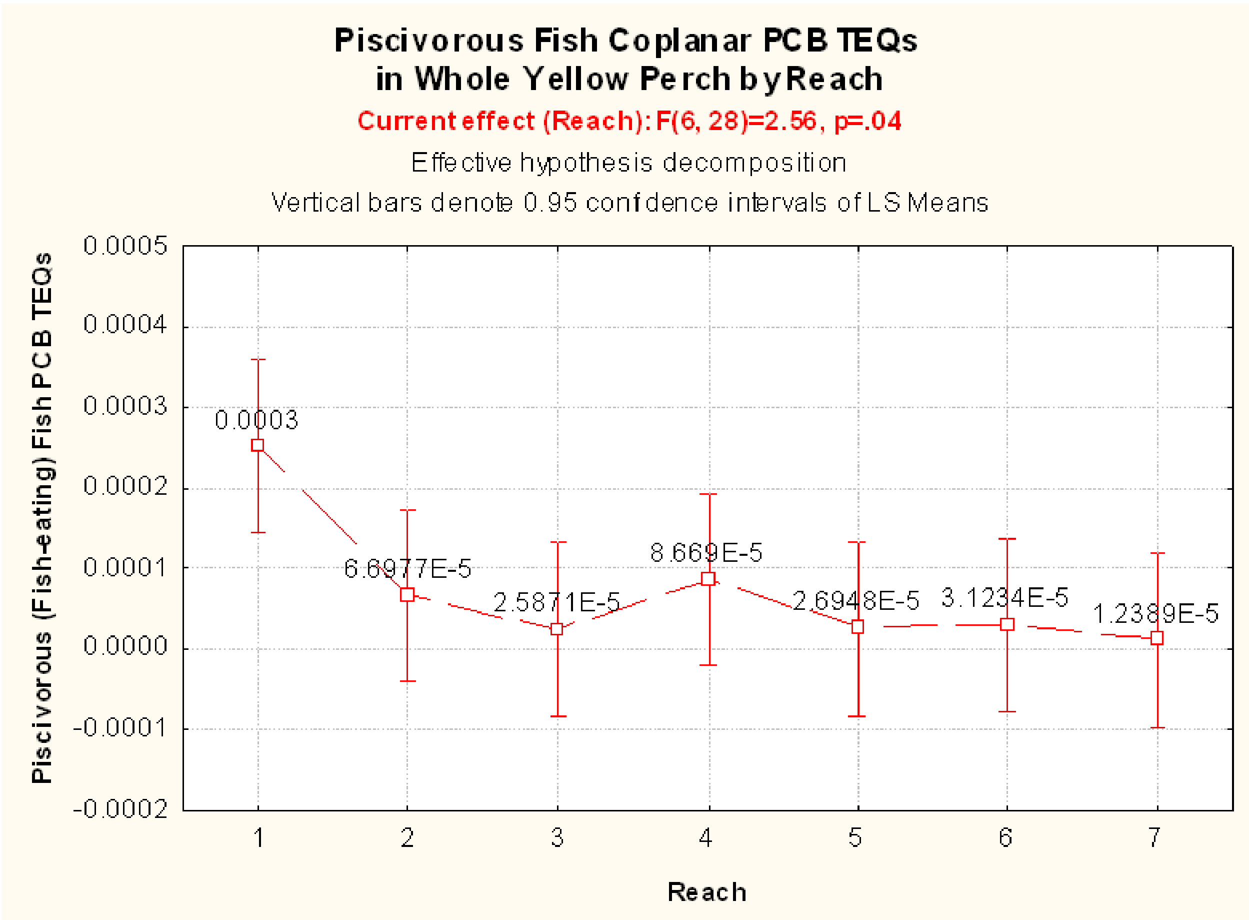

Figure 78. ANOVA of Piscivorous (Fish-eating) Fish Coplanar PCB TEQs (ppb) in CT River Whole Yellow Perch by Reach

A one-way ANOVA found a significant effect for Reach (p=0.04) in piscivorous (fish-eating) fish coplanar PCB TEQs in whole yellow perch (Figure 78). Table 41 summarizes the pair-wise comparison of fish-eating coplanar PCB TEQs in whole yellow perch by Reach using Fisher's LSD Test. Reach 1 was significantly higher than all other Reaches.

Table 41. Statistical Comparison of Fish-eating Bird Coplanar PCB TEQs in Whole Yellow Perch by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	0.00025	0.00007	0.00003	0.00009	0.00003	0.00003	0.00001
Reach	**1 2**	**3**	**4**	**5**	**6**	**7**	
1		**0.02**	**4.87E-03**	**0.03**	**0.01**	**0.01**	**3.08E-03**
2			0.58	0.79	0.59	0.63	0.47
3				0.42	0.99	0.94	0.86
4					0.43	0.46	0.32
5						0.95	0.85
6							0.80

3.8.3.3 White Suckers

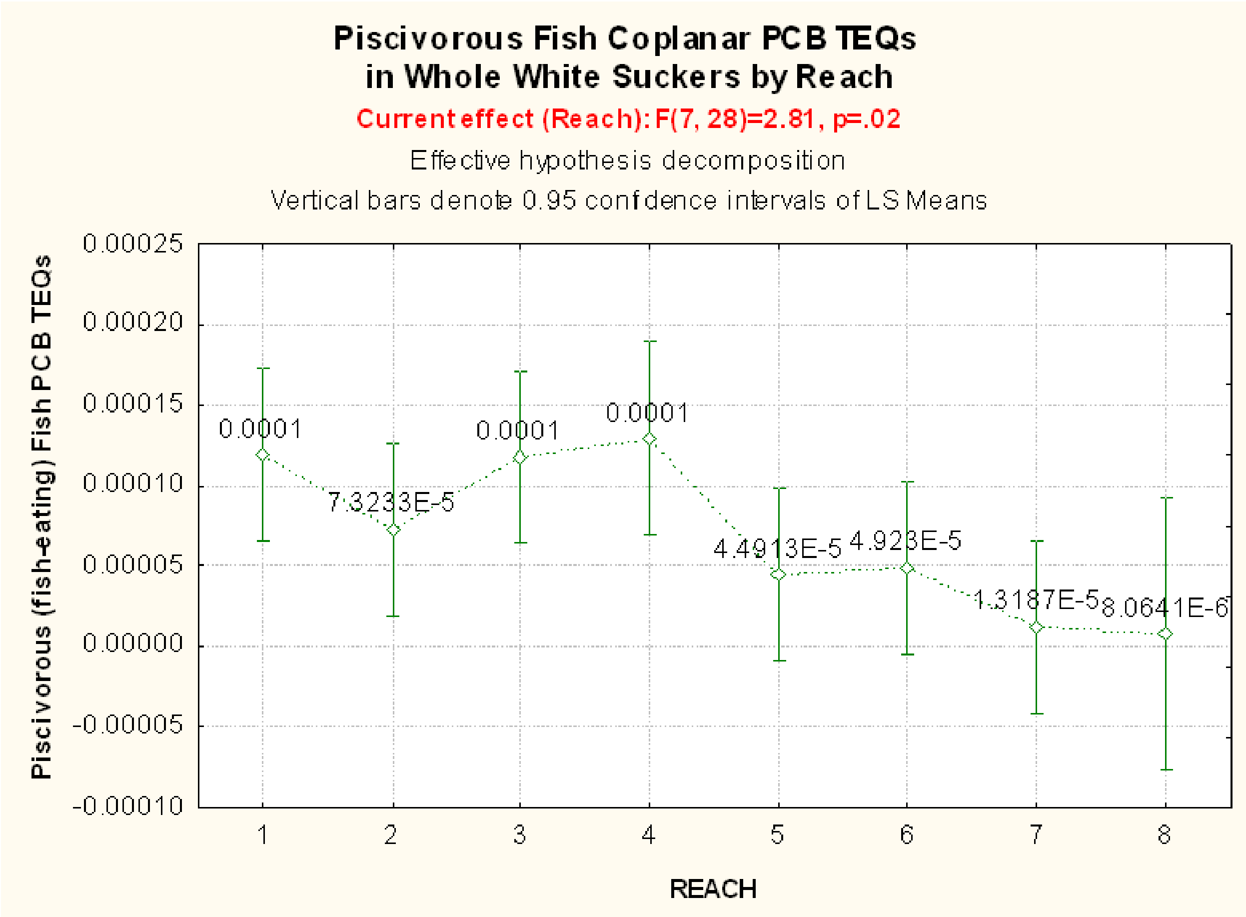

Figure 79. ANOVA of Piscivorous (Fish-eating) Fish Coplanar PCB TEQs (ppb) in CT River Whole White Suckers by Reach

A one-way ANOVA found a significant effect for Reach (p=0.02) in piscivorous (fish-eating) fish coplanar PCB TEQs in whole white suckers (Figure 79). Table 42 summarizes the pair-wise comparison of fish-eating coplanar PCB TEQs in whole white suckers by Reach using Fisher's LSD Test. Reach 1 was significantly higher than Reaches 5, 7, and 8. Reach 3 was significantly higher than Reaches 7 and 8. Reach 4 was significantly higher than Reaches 5, 6, 7, and 8.

Table 42. Statistical Comparison of Fish-eating Bird Coplanar PCB TEQs in Whole White Suckers by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	0.00012	0.00007	0.00012	0.00013	0.00004	0.00005	0.00001	0.00001
REACH	1 2	3	4	5	6	7	8	
1		0.22	0.97	0.80	**0.05**	0.07	**0.01**	**0.03**
2			0.23	0.16	0.45	0.52	0.11	0.19
3				0.78	0.06	0.07	**0.01**	**0.03**
4					**0.04**	**0.05**	**0.01**	**0.02**
5						0.91	0.40	0.46
6							0.34	0.41
7								0.92

3.8.3.4 Piscivorous (Fish-eating) Fish Coplanar PCB TEQs - ANOVA Summary

A factorial ANOVA found a significant effect (p=0.02) in piscivorous (fish-eating) fish coplanar PCB TEQs in whole fish by species and Reach. Reach 4 in smallmouth bass was significantly higher than all other combinations of Reaches and species. Significant differences were also found between Reach 1 in yellow perch with Reaches 3, 5, 6, and 7 in yellow perch. Reach 1 in yellow perch was also significantly different than smallmouth bass in Reaches 6 and 7 and white suckers in Reach 7.

A one-way ANOVA found a significant effect for Reach (p=0.02) in piscivorous (fisheating) fish coplanar PCB TEQs in whole smallmouth bass. In whole smallmouth bass piscivorous fish coplanar PCB TEQs in Reach 4 were significantly higher than all other Reaches.

A one-way ANOVA found a significant effect for Reach (p=0.04) in piscivorous (fisheating) fish coplanar PCB TEQs in whole yellow perch. Reach 1 was significantly higher than all other Reaches.

A one-way ANOVA found a significant effect for Reach (p=0.02) in piscivorous (fisheating) fish coplanar PCB TEQs in whole white suckers. Reach 1 was significantly higher than Reaches 5, 7, and 8. Reach 3 was significantly higher than Reaches 7 and 8. Reach 4 was significantly higher than Reaches 5, 6, 7, and 8.